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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

FOR THE

NEW YORK MEETING

FEBRUARY 25–26, 1938

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

COLUMBIA UNIVERSITY

For Program of session of the Optical Society see Pages 5 to 11
For Program of sessions of the Physical Society see Pages 11 to 27

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The American Physical Society

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BULLETIN

of the

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FEBRUARY 4, 1938 Vol. 13, No. 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 25–26, 1938

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

THE 219th regular meeting of the American Physical Society will be held in New York City on Friday and Saturday, February 25–26, 1938 as a joint meeting with the Optical Society of America. All regular sessions for the reading of papers for both the Physical Society and Optical Society will be held at Columbia University in the Pupin Physics Laboratories on 120th Street east of Broadway (entrance at 119th Street and Broadway).

Joint Session. On Friday morning at 9:30 o'clock there will be a joint session of the two Societies in Room 401. This session will be a symposium on *The Optical Properties of Metals.*

Regular Sessions. For details of the regular sessions of contributed papers see the Calendar on the following page.

Dinner. On Friday evening at 6:00 o'clock there will be a joint dinner for the members of the two Societies and their friends at the Columbia University Men's Faculty Club (corner 117th Street and Morningside Drive). The President of the Physical Society, Dr. Lyman J. Briggs of the National Bureau of Standards, will preside. The price of the dinner will be $1.25 per plate. Tickets will be on sale at the Pupin Physics Laboratories, Columbia University. Reservations should be made as early as possible and not later than Friday at 3 P.M.

Luncheon. On Friday and Saturday luncheon may be had at the Columbia University Men's Faculty Club. Further announcement will be made at the Friday and Saturday sessions.

A Symposium on the Physics of the Universe and the Nature of Primordial Particles will be held at the University of Notre Dame on May 2 and 3, 1938. Addresses will be delivered by Carl D. Anderson, California Institute of Technology; G. Breit, University of Wisconsin; J. F. Carlson, Purdue University; Arthur H. Compton, University of Chicago; Eugene Guth, University of Notre Dame; Arthur E. Haas, University of Notre Dame; W. D. Harkins, University of Chicago; Georges Lemaître, University of Louvain, visiting professor at the University of Notre Dame; Harlow Shapley, Harvard University; and M. S. Vallarta, Massachusetts Institute of Technology.

Physics in the Automotive Industry. A symposium on *Physics in the Automotive Industry* will be held under the auspices of the American Institute of Physics in Ann Arbor, Michigan, March 14 and 15, 1938. The Department of Physics at the University of Michigan will act in the capacity of host. There will be a group of distinguished speakers stressing the importance of physics in the automotive industry.

Subjects to be discussed will include the general relationship of physics to the automotive industry, scientific training and a number of technical topics such as seeing and lighting in connection with highway hazards, lubrication, noise measurement and other phases of automotive acoustics, physical methods of studying engine combustion, instruments, spectrochemical analysis, theory of materials, and others.

Anyone interested in attending the symposium will be welcome and will be sent a special notice

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of exact dates and general arrangements upon request sent to the American Institute of Physics, 175 Fifth Avenue, New York, N. Y.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

220. April 28–30, 1938. Washington, D. C.
221. June, 1938. Pacific Coast. Time and place to be decided.
222. June 24–25, 1938. Toronto, Canada.

W. L. Severinghaus, *Secretary*
Columbia University, New York, N. Y.

February 4, 1938.

CALENDAR

Friday morning, February 25, 1938

9:30 o'clock: Pupin Physics Laboratories: Room 818: Meeting of the Council of the Physical Society.

9:30 o'clock: Pupin Physics Laboratories: Room 401: Joint Session of the two Societies: *Symposium on The Optical Properties of Metals*. See page 5.

Friday afternoon, February 25, 1938

2:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society Papers 4–10. See pages 6–7.

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society Papers 1–12. See pages 11–14.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society Papers 13–22. See pages 14–15.

Friday evening, February 25, 1938

6:00 o'clock: Columbia University Men's Faculty Club: Joint dinner of the two Societies.

8:15 o'clock: American Museum of Natural History: Adolph Lomb Memorial Lecture: Dr. Harlow Shapley on *The Debt of the World to Optical Science*.

Saturday morning, February 26, 1938

9:30 o'clock: Pupin Physics Laboratories: Room 401: Physical Society Papers 23–34. See pages 16–18.

9:30 o'clock: Pupin Physics Laboratories: Room 329: Physical Society Papers 35–44. See pages 18–20.

10:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society Papers 11–18. See pages 8–11.

Saturday afternoon, February 26, 1938

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society Papers 45–56. See pages 20–23.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society Papers 57–66. See pages 23–25.

THE OPTICAL SOCIETY OF AMERICA

OFFICERS

President, R. C. GIBBS, Cornell University
Vice President, K. S. GIBSON, National Bureau of Standards
Secretary, L. B. TUCKERMAN, National Bureau of Standards
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Board of Directors: Consists of the above officers and A. C. HARDY, *Past President*, F. K. RICHTMYER, *Editor*, AND BRIAN O'BRIEN, H. P. GAGE, G. R. HARRISON, AND WILLIAM F. MEGGERS, *Directors-at-large.*

Adolph Lomb Memorial Lecture

The Optical Society will inaugurate the Adolph Lomb Memorial Lectures at 8:15 P.M. Friday, February 25, in the large auditorium of the American Museum of Natural History at Central Park West and 77th Street. Dr. Harlow Shapley, director of the Harvard University Observatory, will speak on "The Debt of the World to Optical Science."

Adolph Lomb was the first treasurer of the Optical Society, taking office when the Society was founded in 1916 and serving until his death in 1932. Without his wisdom, interest and financial assistance, the Optical Society probably could not have been launched and nursed into maturity. The Society, knowing its debt to his memory, has set aside a fund known as the Adolph Lomb Memorial Fund. The first use of the income from this fund will be for the arrangement of memorial lectures. These lectures, the inaugural of which is here announced, will be presented by the most distinguished obtainable speakers. They will be devoted to the field of optical science and the purposes for which the Optical Society itself exists.

Inter-Society Color Council Annual Meeting Electrical Testing Laboratories, New York February 24, 1938

The Intersociety Color Council is an organization of National Societies and of individual members interested in the standardization, description and specification of color.

The Optical Society of America was active in the organization of the Council in 1931 and has maintained its membership in the Council since its organization.

As many members of the Optical Society are interested and active in the work of the Council the program of its sessions is given below.

All persons interested are cordially invited to attend the technical sessions Thursday afternoon and evening.

1st Session at 9:30 a.m.—Annual Business Meeting

Luncheon at 1:00 o'clock

2nd Session at 2:00 p.m.—Technical

1. **History of the Design of the Spectrophotometer.** A. C. HARDY, *Massachusetts Institute of Technology, Boston, Mass.*
2. **Construction of the Spectrophotometer.** J. L. MICHAELSON, *General Electric Company, Schenectady, N. Y.*
3. **Calibration and Operation of Spectrophotometer.** K. S. GIBSON, *National Bureau of Standards, Washington, D. C.*
4. **Application of Spectrophotometric Data to the Printing Industry.** C. E. FOSS, *International Printing Ink Corp., New York, N. Y.*
5. **Identification of Gelatins for Theatrical Lighting.** D. B. JUDD, *National Bureau of Standards, Washington, D. C.*

Supper at 6:30 P.M.

3rd Session at 8:00 p.m.—Popular

1. **Psychology of Color.** F. L. DIMMICK, *Hobart College, Geneva, N. Y.*
2. **Color in Interior Design.** ETHEL LEWIS, *Associate Editor, Interior Design and Decoration, New York, N. Y.*
3. **Solar Corona, Painting and Description.** C. BITTINGER, *Artist, Washington, D. C.*
4. **Colored Motion Pictures of the Growing of Crystals Under Polarized Light.** L. A. JONES, *Eastman Kodak Company, Rochester, N. Y.*

PROGRAM

FRIDAY, FEBRUARY 25, AT 9:30 O'CLOCK

Room 401

Joint Session of The American Physical Society and The Optical Society of America

SYMPOSIUM ON

THE OPTICAL PROPERTIES OF METALS

Invited Papers

1. **Some Simple Concepts in the Quantum Theory of Metals.** L. A. DUBRIDGE, *University of Rochester.*
2. **The Experimental Determination of Optical Constants of Metals—Methods and Results.** J. B. NATHANSON, *Carnegie Institute of Technology.*
3. **Derivation of Properties of Electrons in Metals from Optical Constants.** H. A. BETHE, *Cornell University.*

FRIDAY, FEBRUARY 25, AT 2:00 O'CLOCK

Room 428

Contributed Papers

(For simultaneous sessions of the Physical Society, Rooms 329 and 401, see pages 11–15)

4. Photoelectrically Balanced Recording Potentiometer.* C. OWEN FAIRCHILD AND V. LAWRENCE PARSEGIAN, *C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.* (10 minutes.)

The problem of stopping a moving light beam on the edge of a phototube without any tendency to oscillate or "hunt," and with speed and precision has been solved by a new method and a recording potentiometer is rapidly and accurately balanced. By (1) artificially canceling the generated back e.m.f. of the moving galvanometer, thus advancing its return movement from a deflected position, and by (2) delaying the grid potential change of a triode amplifier in the photoelectric circuit, galvanometer lag is counteracted and the potentiometer is balanced with an accuracy of a few hundredths of a percent of the range. The total power input of the instrument is about 35 watts and the contact carriage speed is made as high as 10″ in 20 seconds. The fundamentals of the complete instrument are discussed and equations describing the galvanometer movement are included.

Bibliography:

1. Hazen, Jaeger and Brown, Rev. Sci. Inst. **7**, 353 (1936).
2. Whitford and Kron, Rev. Sci. Inst. **8**, 78 (1937).
3. Instruments **8**, 343 (1935).
4. Culliksen and Vedder, "Industrial Electronics" (John Wiley & Sons, 1935).

* The present paper will appear in full in R. S. I.

5. The Second Spectrum of Vanadium.* WILLIAM F. MEGGERS, *National Bureau of Standards*, AND CHARLOTTE E. MOORE, *Princeton University*. (10 minutes.)

A partial analysis of the V II spectrum presented by one of us[1] in 1926 classified about 280 lines as combinations of 11 triplet and 9 quintet terms, but further progress was prevented by inadequate data. Last year, a new description of vanadium spark spectra was prepared and the term analysis of the V II spectrum was resumed. At the present time nearly 1200 lines have been explained as combinations of 21 singlet, 37 triplet, and 12 quintet terms. Theoretically, the electron configurations $3d^4$ and $3d^34s$ each give rise to 16 terms. All of these have been found except 2 high singlets of the former and 1 high singlet of the latter. The ground state of the V^+ ion is represented by $(3d^4)^5D_0$ and the spectroscopic ionization potential is approximately 14 volts. Observations of the Zeeman effect by H. D. Babcock have greatly facilitated this analysis of the second spectrum of vanadium.

* The present paper will appear in full in Nat. Bur. Stand. J. Research.

[1] W. F. Meggers, Zeits. f. Physik **33**, 509 (1925); Ibid. **39**, 114 (1926).

6. Radiation Laws Describing the Emission of Photons by Black Bodies. A. G. WORTHING, *University of Pittsburgh*. (10 minutes.)

Haas and Guth (Indianapolis Meeting, December, 1937) showed that the rate of emission of photons by a black body, regardless of their energy contents, varies as T^3. The question rises, what are the other black body laws which describe the radiation from the same standpoint? For the displacement law, the procedure is much like that involved in the deduction of Wien's law. Starting with an opaque, evacuated, spherical enclosure with perfectly reflecting walls, which is filled with black body radiation, one considers an adiabatic change of volume and obtains the well known relation,

$$\mu_\nu \Delta\nu / \mu_{\nu_0} \Delta\nu_0 = (T/T_0)^4$$

where $\mu_\nu \Delta\nu$ represents the density of radiant energy associated with the range of frequency $\Delta\nu$ in the neighborhood of the frequency ν. An initial or standard state is indicated by subscript zero. Corresponding photon densities or concentration $C_\nu \Delta\nu$ and $C_{\nu_0}\Delta\nu_0$ are obtained by dividing the radiant energy densities by $h\nu$ and $h\nu_0$. Treatment of the equation obtained by standard procedure yields $C_\lambda = T^4 f(\lambda T)$ which differs only in the power of T from Wien's equation, namely $\mu_\lambda = T^5 f(\lambda T)$. Analogous to the simpler form of Wien's equation, we have another, $\lambda_m T = \text{constant}$, with the constant in this case equal to $14{,}320\mu K°/3.921$. Analogous to Planck's law, we have, as used by Haas and Guth, $C_\lambda = (8\pi/\lambda^4)[1/(e^{c_2/\lambda T} - 1)]$ of which the right-hand member differs from the corresponding Planck form by the factor hc/λ. The relations presented are thought to be of value in connection with photoelectric and photochemical processes.

7. Correlation of Optical Properties and Photoelectric Emission in Thin Films of Alkali Metals.* HERBERT E. IVES AND H. B. BRIGGS, *Bell Telephone Laboratories*. (20 minutes.)

According to the theory proposed some time ago,[1] the photoelectric emission from continuous thin films of alkali metal deposited on specular surfaces of other metals, such as platinum, is proportional to the energy absorbed by the alkali metal. This absorption is determined by the absorptive properties of the alkali metal, which are obtainable from its optical constants, and the energy density occurring immediately above the supporting metal, which is obtainable from its optical constants. This theory gives an immediate explanation for the characteristic high ratio of emission for the two principal planes of polarization of the incident light, but has needed, for its test at various wave-lengths, data on the optical constants, through the spectrum, of the alkali metals. These are now available[2] and have been used to calculate the expected photoelectric emission. Concurrently a series of measurements have been made with improved apparatus and technique upon potassium, rubidium and cesium (the crucial phenomena predicted for sodium lie outside the utilizable spectrum range). The spectral emission curves obtained from the

three metals, for equilibrium films, show spectral maxima of the predicted character. In each case the experimental curves are broader than those predicted for exceedingly thin (monatomic) films and the maxima are shifted toward shorter wave-lengths. Upon assuming thicknesses greater than monatomic for the films, the computed curves both broaden and shift toward the violet, yielding finally, for certain choices of thickness, a close correspondence with the experimental results.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] Phys. Rev., Sept. 15, 1931, p. 1209.
[2] J. Opt. Soc. Am. **26**, 238 (1936); **27**, 181 and 395 (1937).

8. Dispersion Formulae and Color Correction.* M. HERZBERGER, *Kodak Research Laboratories.* (15 minutes.)

The measurements of Kingslake on refractive indices in infra-red show that neither Hartmann's formula, nor related formulae, can give a true dispersion formula, but that the old Helmholtz-Ketteler formula

$$n^2 = a + [b/(\nu^2 - \nu_0^2)] + c\nu^2$$

is the only satisfactory one. The author tried it on all the glasses in the manufacturers' catalogs, with the result that he could approximate all glasses with an accuracy of a few units in the fifth decimal throughout the visible spectrum. The formulae allow extrapolation into the near infra-red. Study of the color correction in optical systems brought the proposal to abandon Abbe's ν value as characterizing the dispersion qualities of optical glass. The author proposes instead of this the use of a dispersion function which is zero for a fundamental color and which can be characterized by its value for two other colors. The author shows how the well-known formulae for color correction of thin and thick lens combinations simplify, when this dispersion function is introduced which is proportional and not reciprocal to the dispersion of the magnitude investigated.

* The present paper will appear in full in J. Opt. Soc. Am.

9. Some New Physiological and Toxicological Effects of Roentgen Rays.* DAVID I. MACHT, *Pharmacological Research Laboratory, Hynson, Westcott & Dunning, Inc., Baltimore, Maryland.* (15 minutes.)

The author's interest in roentgen sickness, a not infrequent occurrence in patients undergoing x-ray therapy, was the starting-point of the present investigation. Zoöpharmacological experiments were performed on ten species of animals and phytopharmacological tests were made on various seeds and on seedlings of *Lupinus albus.*[1] Bloods obtained from the different animals while in normal condition and those taken after their exposure to x-rays were studied and compared by special pharmacological methods devised by the author.[2] The most important finding was the discovery that the blood of the various animals undergoing roentgen irradiation contains a toxic substance which usually does not appear until from twelve to twenty-four hours after such treatment and then persists for several days. The amount of toxin present varies with the region treated with x-rays. After roentgen irradiation, smooth muscle organs respond to pharmacodynamic reagents with a slight decrease in contractility. Studies by a modification of the Thunberg method[3] on oxidation and reduction phenomena in freshly excised brain tissue from animals exposed to x-rays, and from controls which were not, reveal that roentgen irradiation effects some impairment of enzymatic activity followed by recovery if dosage is not excessive. Clinical studies on human blood are in progress. Search is also being made for drugs which may counteract the toxicity of x-rays. Plant-physiological experiments were made on the germination of various seeds and on the root growth of *Lupinus albus* seedlings. Growth of *Lupinus albus* seedlings exposed to from 300 to 500R units was accelerated. Larger doses inhibited root growth. Suitable doses of roentgen rays increased percentage of germination of seeds of wheat, oats, tomato and *Lupinus albus* and also accelerated growth of the embryo plants. Larger doses produced inhibitory or toxic effects.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] Macht and Livingston, J. Gen. Physiol. **4**, 573 (1922).
[2] Macht, Arch. Dermat. and Syph. **36**, 1022 (1937).
[3] Macht and Bryan, J. Am. Chem. Soc. **58**, 729 (1936).

10. Intensity and the Visibility of Wires.* SELIG HECHT AND ESTHER U. MINTZ, *Columbia University.* (25 minutes.)

We have measured with white light the relation between the visual angle subtended by a wire which just becomes visible, and the brightness of the field behind it. The diameter of the field and the length of the wire were about 15°. Over the whole range of brightness the relation shows two sections, one at low illuminations and another at high illuminations expressing rod and cone activities, respectively, as usually found in visual functions. Considered as recording visual acuity, the widths of the wires represent a variation from 0.07 unit of visual acuity at the very lowest intensities to 120 units at the highest. In this form, the relation between visual acuity and intensity resembles those found with more usual test objects like hooks, broken circles or gratings except that ours covers a greater extent. The common range is about 1 to 60 whereas ours covers more nearly 1 to 1500 of which 1 to 100 is the cone range and 1 to 15 is the rod range. The maximum visual acuity corresponds to an angle of 0.5 second, and to a geometrical image 0.04μ wide at the retina, and is thus about 1/65 of the diameter of a central cone. The data may also be considered as measurements of intensity discrimination. The wire or its image decreases the total illumination on a line of retinal elements by an amount ΔI where I is the general illumination of the field. The angle subtended by the width of the wire then measures $\Delta I/I$, and it is possible that the wire is recognized when the value of $\Delta I/I$ becomes critical for the prevailing intensity. The data actually correspond to the intensity discrimination function, as measured by various investigators. It may therefore be that visual acuity measurements are basically determined by the intensity discrimination function, though other factors such as pupil diameter for a grating and the size of retinal elements are undoubtedly involved.

* The present paper will appear in full in J. Gen. Physiol.

FRIDAY, FEBRUARY 25, AT 6:00 O'CLOCK

Columbia University Men's Faculty Club: Joint dinner of the two Societies

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FRIDAY, FEBRUARY 25, AT 8:15 O'CLOCK

American Museum of Natural History
Central Park West at 77th Street (77th Street Entrance)
Large Auditorium

Adolph Lomb Memorial Lecture

The Debt of the World to Optical Science

BY

DR. HARLOW SHAPLEY
Director of the Harvard College Observatory

SATURDAY, FEBRUARY 26, AT 10:00 O'CLOCK

Room 428

Contributed Papers

(For simultaneous sessions of the Physical Society, Rooms 329 and 401, see pages 16–20)

11. Colorimetry of the Purkinje and Hering Images.* SIDNEY M. NEWHALL, *Johns Hopkins University.* (15 minutes.)

Purkinje and Hering after-images[1] were induced by 0.2 sec. stimulation of a paramacular retinal area. Colorimetry was accomplished by projecting the after-image to the viewing plane of a special tristimulus colorimeter[2] and there matching to it the primary image of the colorimetric mixture. The rather exacting technique requires some special training and precision is low relative to usual colorimetry. The difficulty is due in large measure to the short duration of the aptly termed "flash" images under investigation. Blue arcs enduring 0.5 sec. had been matched without much trouble.[3] Chromatic stimuli of several sorts were employed to permit comparison of after-images and complementaries corresponding to different primary images. The retinal illumination from each sort of stimulus was varied through a range sufficient to include the critical region of transformation from Purkinje to Hering image. Trilinear coordinates and derived measures of these images will be discussed.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] D. B. Judd, Am. J. Psychol. **38**, 507 (1927).
[2] S. M. Newhall, Psychol. Mon. **47**, 199 (1936).
[3] S. M. Newhall, J. Opt. Soc. Am. **27**, 165 (1937).

12. Photometric Relationships Between Complementary Colors.* D. L. MACADAM, *Kodak Research Laboratories.* (10 minutes.)

Two complementary chromaticities must be additively mixed in the proper brightness ratio in order to produce a neutral mixture. This ratio, L, can be computed from any one of the following expressions:

$$L/y+1/y'=(1+L)/y_n,$$
$$L=(y'/y)\cdot(y-y_n)/(y_n-y'),$$
$$L=(y'/y)\cdot(x-x_n)/(x_n-x').$$

The symbols, x, y, and x', y', are the coordinates of the complementary chromaticities in the I.C.I. chromaticity diagram, in which the point x_n, y_n represents the chromaticity of the desired "neutral" or gray mixture. The three points (x, y), (x_n, y_n), (x', y') must be collinear in this order. Neither of the complementaries need be spectrum colors, but the equations may be used to determine the brightness ratios of spectrum complementaries necessary for neutral mixtures. The great brightness ratios resulting from the low luminosity of the blue end of the spectrum are inconvenient for graphical representation, and can be avoided if the energy ratios of complementary spectrum lights necessary for a neutral mixture are computed. Loci can be traced in the I.C.I. chromaticity diagram to give the "moment" of one millilambert of every chromaticity with respect to any assigned neutral stimulus. The brightness ratio of two complementary chromaticities necessary for a neutral mixture is the reciprocal of their moments per millilambert with respect to the neutral. The locus of constant moment (per millilambert), m, is a conic section having the $y=0$ axis as its directrix, the neutral point as its focus and the moment, m, as its eccentricity. This diagram is of immediate use in the plane vector solution of any problem of additive color mixture. The vector solution of the problem encountered in the projection of additive photographs, the determination of the brightness ratios of the three primaries necessary for a neutral screen, will be outlined. The "neutral" chromaticity desired on the screen need not be the neutral with respect to which the moment loci

are drawn. The colorimetric purity of any color is the ratio of the moment per millilambert of that color to the moment per millilambert of the spectrum color collinear with the neutral and the sample color.

* The present paper will appear in full in J. Opt. Soc. Am.

13. Effects of Multiple Reflection Between Surfaces of a Light Filter.* HOWARD J. ECKWEILER, *New York University.* (10 minutes.)

A study of the effects of multiple reflection between the interfaces of a homogeneous light-filter upon its transmission. Instances where these small effects may lead to appreciable error if they are ignored are cited.

* The present paper will appear in full in J. Opt. Soc. Am.

14. A New Luminosity Filter. KASSON S. GIBSON, RAY P. TEELE AND HARRY J. KEEGAN, *National Bureau of Standards.* (15 minutes.)

In 1919, Ives published a specification[1] for a luminosity (visibility) filter, the principal constituents of which were copper chloride, cobalt ammonium sulphate, and potassium dichromate. The relative spectral transmission of this filter was a close duplicate of the relative luminosity (visibility) curve, except at the short wave-lengths where the absorption of the dichromate was too strong, the transmission of the filter being practically zero below 460 mμ. This defect, however, was of little importance in the use of the filter at that time in physical photometry, since most of the illuminants were then of very low relative-energy content in the blue and violet. With the gas-filled tungsten lamps and the numerous gas-discharge tubes now in use, however, it was necessary to devise a new luminosity filter for use with the thermopile if the resulting physical photometer were to prove adequate for standardization purposes. Since no adjustment of the dichromate in Ives's solution would importantly improve the filter, it was necessary to find a substitute for this component. Some years ago, it had been noticed that a certain piece of Corning G 34 glass, having an "unsharp cut-off," gave a relatively good fit with the standard I.C.I. luminosity (visibility) curve[2] in the blue region. By means of this filter and with the published Davis-Gibson data[3] on copper sulphate and cobalt ammonium sulphate, together with a small amount of potassium dichromate to control the curve in the violet, very good duplication of the I.C.I. luminosity curve has been obtained. This will be illustrated. The principal defect of the filter is, of course, its lack of reproducibility, resulting from use of the yellow glass. A melt of the G 34 glass which does not have the "sharp cut-off" is apparently obtained only accidentally and has hitherto been considered undesirable. It certainly is not reproducible. In an effort to remedy this situation, the National Bureau of Standards has obtained the small remaining stock of this glass from Corning Glass Works and may possibly be able to issue this part of the filter to those who wish to construct a physical photometer.

[1] H. E. Ives, "The Photometric Scale," J. Frank. Inst. **188**, 217 (1919).
[2] K. S. Gibson and E. P. T. Tyndall, Nat. Bur. Stand. Sci. Pap. 475 (1923).
[3] Nat. Bur. Stand. Misc. Pub. No. 114 (1931).

15. Further Study of the Use of Filters and Barrier-Layer Photo-Cells for Tristimulus Colorimetry. RICHARD S. HUNTER, *National Bureau of Standards.* (15 minutes.)

A paper[1] on the development of equipment and methods for photoelectric tristimulus colorimetry was given at the 1937 fall meeting of the Optical Society. It was shown that the G.E. barrier-layer photo-cell was well suited for this type of colorimetry and a set of filters was described for use with this cell and incandescent source. Since this previous paper, improvements have been made in the amber and blue filters; the best available filters known at the present time being: (a) For the "*X*" function (with that portion of the function between 380 and 500 mμ made zero): Corning 330 Signal Yellow, 6.7 mm of melt of 11–9–31, with Corning 397 Medium Shade Aklo, 3.0 mm thick. (b) For the "*Y*" function: Same as described previously. (c) For the "*Z*" function: Corning 554 Lantern Blue, 5.0 mm of melt of 2–13–35, with Corning Noviol A Pale, 2.5 mm of melt of 8–1–36. It is the purpose of the present paper to discuss the use of data obtained with these source-filter-photo-cell combinations for the description and specification of colorimetric quantities. Attention has been centered on the development of two methods for the treatment of the data: (1) The first method has sought the most satisfactory means for the conversion of experimental tristimulus data to specifications on the standard I.C.I. basis. It is shown that, because of failure to duplicate sufficiently the ideal spectral functions in the source-filter-photo-cell combinations, conversions to the I.C.I. basis are not possible with a high degree of accuracy unless material standards are employed which are similar in spectral characteristics to the samples being measured and which have I.C.I. specifications accurately determined by some other method. The most satisfactory transformation equations for these conversions will be given and the results of a number of transformations reported. (2) The second project has sought a method for using photoelectric tristimulus data in the description and measurement of colorimetric quantities on a uniform-color-tolerance basis. A uniform-chromaticity-scale triangle was sought which would be similar in shape to Judd's[2] triangle and which would have rectangular axes, as do the triangles described by Breckenridge and Schaub[3] and MacAdam.[4] At the 1937 fall meeting of the Optical Society, Judd[5] reported on an empirical equation designed to give uniform color tolerances for surface-color specifications. This equation has been rewritten to include only quantities which may be measured by the photoelectric tristimulus method. Comparisons will be given of a number of color differences measured by Judd's method and by the photoelectric tristimulus method.

[1] R. S. Hunter, Abstract No. 16, Program of 22nd Annual Meeting O. S. A. Oct. 14–16, 1937.
[2] J. Opt. Soc. Am. **25**, 24 (1935).
[3] J. Opt. Soc. Am. **27**, 226 (1937).
[4] J. Opt. Soc. Am. **27**, 294 (1937).
[5] Abstract No. 19, Program of 22nd Annual Meeting O. S. A. Oct. 14–16, 1937.

16. Selected Ordinates for Luminosity Computations with Black Body Illuminants between 2000°K and 4000°K.* D. L. MACADAM, *Kodak Research Laboratories.* (10 minutes.)

Wave-lengths have been calculated for use in the thirty selected ordinate method for computing the visual reflec-

FRIDAY, FEBRUARY 25, AT 6:00 O'CLOCK

Columbia University Men's Faculty Club: Joint dinner of the two Societies

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FRIDAY, FEBRUARY 25, AT 8:15 O'CLOCK

American Museum of Natural History
Central Park West at 77th Street (77th Street Entrance)
Large Auditorium

Adolph Lomb Memorial Lecture

The Debt of the World to Optical Science

BY

DR. HARLOW SHAPLEY
Director of the Harvard College Observatory

SATURDAY, FEBRUARY 26, AT 10:00 O'CLOCK

Room 428

Contributed Papers

(For simultaneous sessions of the Physical Society, Rooms 329 and 401, see pages 16–20)

11. Colorimetry of the Purkinje and Hering Images.* SIDNEY M. NEWHALL, *Johns Hopkins University.* (15 minutes.)

Purkinje and Hering after-images[1] were induced by 0.2 sec. stimulation of a paramacular retinal area. Colorimetry was accomplished by projecting the after-image to the viewing plane of a special tristimulus colorimeter[2] and there matching to it the primary image of the colorimetric mixture. The rather exacting technique requires some special training and precision is low relative to usual colorimetry. The difficulty is due in large measure to the short duration of the aptly termed "flash" images under investigation. Blue arcs enduring 0.5 sec. had been matched without much trouble.[3] Chromatic stimuli of several sorts were employed to permit comparison of after-images and complementaries corresponding to different primary images. The retinal illumination from each sort of stimulus was varied through a range sufficient to include the critical region of transformation from Purkinje to Hering image. Trilinear coordinates and derived measures of these images will be discussed.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] D. B. Judd, Am. J. Psychol. **38**, 507 (1927).
[2] S. M. Newhall, Psychol. Mon. **47**, 199 (1936).
[3] S. M. Newhall, J. Opt. Soc. Am. **27**, 165 (1937).

12. Photometric Relationships Between Complementary Colors.* D. L. MACADAM, *Kodak Research Laboratories.* (10 minutes.)

Two complementary chromaticities must be additively mixed in the proper brightness ratio in order to produce a neutral mixture. This ratio, L, can be computed from any one of the following expressions:

$$L/y+1/y'=(1+L)/y_n,$$
$$L=(y'/y)\cdot(y-y_n)/(y_n-y'),$$
$$L=(y'/y)\cdot(x-x_n)/(x_n-x').$$

The symbols, x, y, and x', y', are the coordinates of the complementary chromaticities in the I.C.I. chromaticity diagram, in which the point x_n, y_n represents the chromaticity of the desired "neutral" or gray mixture. The three points (x, y), (x_n, y_n), (x', y') must be collinear in this order. Neither of the complementaries need be spectrum colors, but the equations may be used to determine the brightness ratios of spectrum complementaries necessary for neutral mixtures. The great brightness ratios resulting from the low luminosity of the blue end of the spectrum are inconvenient for graphical representation, and can be avoided if the energy ratios of complementary spectrum lights necessary for a neutral mixture are computed. Loci can be traced in the I.C.I. chromaticity diagram to give the "moment" of one millilambert of every chromaticity with respect to any assigned neutral stimulus. The brightness ratio of two complementary chromaticities necessary for a neutral mixture is the reciprocal of their moments per millilambert with respect to the neutral. The locus of constant moment (per millilambert), m, is a conic section having the $y=0$ axis as its directrix, the neutral point as its focus and the moment, m, as its eccentricity. This diagram is of immediate use in the plane vector solution of any problem of additive color mixture. The vector solution of the problem encountered in the projection of additive photographs, the determination of the brightness ratios of the three primaries necessary for a neutral screen, will be outlined. The "neutral" chromaticity desired on the screen need not be the neutral with respect to which the moment loci

are drawn. The colorimetric purity of any color is the ratio of the moment per millilambert of that color to the moment per millilambert of the spectrum color collinear with the neutral and the sample color.

* The present paper will appear in full in J. Opt. Soc. Am.

13. Effects of Multiple Reflection Between Surfaces of a Light Filter.* HOWARD J. ECKWEILER, *New York University.* (10 minutes.)

A study of the effects of multiple reflection between the interfaces of a homogeneous light-filter upon its transmission. Instances where these small effects may lead to appreciable error if they are ignored are cited.

* The present paper will appear in full in J. Opt. Soc. Am.

14. A New Luminosity Filter. KASSON S. GIBSON, RAY P. TEELE AND HARRY J. KEEGAN, *National Bureau of Standards.* (15 minutes.)

In 1919, Ives published a specification[1] for a luminosity (visibility) filter, the principal constituents of which were copper chloride, cobalt ammonium sulphate, and potassium dichromate. The relative spectral transmission of this filter was a close duplicate of the relative luminosity (visibility) curve, except at the short wave-lengths where the absorption of the dichromate was too strong, the transmission of the filter being practically zero below 460 mμ. This defect, however, was of little importance in the use of the filter at that time in physical photometry, since most of the illuminants were then of very low relative-energy content in the blue and violet. With the gas-filled tungsten lamps and the numerous gas-discharge tubes now in use, however, it was necessary to devise a new luminosity filter for use with the thermopile if the resulting physical photometer were to prove adequate for standardization purposes. Since no adjustment of the dichromate in Ives's solution would importantly improve the filter, it was necessary to find a substitute for this component. Some years ago, it had been noticed that a certain piece of Corning G 34 glass, having an "unsharp cut-off," gave a relatively good fit with the standard I.C.I. luminosity (visibility) curve[2] in the blue region. By means of this filter and with the published Davis-Gibson data[3] on copper sulphate and cobalt ammonium sulphate, together with a small amount of potassium dichromate to control the curve in the violet, very good duplication of the I.C.I. luminosity curve has been obtained. This will be illustrated. The principal defect of the filter is, of course, its lack of reproducibility, resulting from use of the yellow glass. A melt of the G 34 glass which does not have the "sharp cut-off" is apparently obtained only accidentally and has hitherto been considered undesirable. It certainly is not reproducible. In an effort to remedy this situation, the National Bureau of Standards has obtained the small remaining stock of this glass from Corning Glass Works and may possibly be able to issue this part of the filter to those who wish to construct a physical photometer.

[1] H. E. Ives, "The Photometric Scale," J. Frank. Inst. **188**, 217 (1919).
[2] K. S. Gibson and E. P. T. Tyndall, Nat. Bur. Stand. Sci. Pap. 475 (1923).
[3] Nat. Bur. Stand. Misc. Pub. No. 114 (1931).

15. Further Study of the Use of Filters and Barrier-Layer Photo-Cells for Tristimulus Colorimetry. RICHARD S. HUNTER, *National Bureau of Standards.* (15 minutes.)

A paper[1] on the development of equipment and methods for photoelectric tristimulus colorimetry was given at the 1937 fall meeting of the Optical Society. It was shown that the G.E. barrier-layer photo-cell was well suited for this type of colorimetry and a set of filters was described for use with this cell and incandescent source. Since this previous paper, improvements have been made in the amber and blue filters; the best available filters known at the present time being: (a) For the "*X*" function (with that portion of the function between 380 and 500 mμ made zero): Corning 330 Signal Yellow, 6.7 mm of melt of 11–9–31, with Corning 397 Medium Shade Aklo, 3.0 mm thick. (b) For the "*Y*" function: Same as described previously. (c) For the "*Z*" function: Corning 554 Lantern Blue, 5.0 mm of melt of 2–13–35, with Corning Noviol A Pale, 2.5 mm of melt of 8–1–36. It is the purpose of the present paper to discuss the use of data obtained with these source-filter-photo-cell combinations for the description and specification of colorimetric quantities. Attention has been centered on the development of two methods for the treatment of the data: (1) The first method has sought the most satisfactory means for the conversion of experimental tristimulus data to specifications on the standard I.C.I. basis. It is shown that, because of failure to duplicate sufficiently the ideal spectral functions in the source-filter-photo-cell combinations, conversions to the I.C.I. basis are not possible with a high degree of accuracy unless material standards are employed which are similar in spectral characteristics to the samples being measured and which have I.C.I. specifications accurately determined by some other method. The most satisfactory transformation equations for these conversions will be given and the results of a number of transformations reported. (2) The second project has sought a method for using photoelectric tristimulus data in the description and measurement of colorimetric quantities on a uniform-color-tolerance basis. A uniform-chromaticity-scale triangle was sought which would be similar in shape to Judd's[2] triangle and which would have rectangular axes, as do the triangles described by Breckenridge and Schaub[3] and MacAdam.[4] At the 1937 fall meeting of the Optical Society, Judd[5] reported on an empirical equation designed to give uniform color tolerances for surface-color specifications. This equation has been rewritten to include only quantities which may be measured by the photoelectric tristimulus method. Comparisons will be given of a number of color differences measured by Judd's method and by the photoelectric tristimulus method.

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16. Selected Ordinates for Luminosity Computations with Black Body Illuminants between 2000°K and 4000°K.* D. L. MACADAM, *Kodak Research Laboratories.* (10 minutes.)

Wave-lengths have been calculated for use in the thirty selected ordinate method for computing the visual reflec-

tance or transmittance of colored materials illuminated with radiation from black bodies at the temperatures: 2000°K, 2200°K, 2360°K, 2600°K, 2848°K, 3000°K, 3200°K, and 4000°K. Each ordinate of any one of these sets is displaced by an almost constant wave-length interval from the corresponding ordinate at any other set. The average value of this displacement is given very accurately (± 0.05 mμ) by the formula:

$$\Delta\lambda = 7.23 \times 10^4 (1/T_1 - 1/T_2) \text{ m}\mu,$$

where the two sets of wave-lengths correspond to black body illuminants having the Kelvin temperatures, T_1 and T_2, between 2000°K and 4000°K. The numerical constant of the above equation is proportional to the value of the constant ($C_2 = 14{,}330$) adopted for use in Planck's formula. Table XVII of the *Handbook of Colorimetry*[1] gives the wave-lengths of the thirty selected ordinates for the I.C.I. illuminant "A" (2848°K) and the I.C.I. "visibility" function, $\bar{y}$. These wave-lengths, increased by the constant given by the following formula, can be used for any black body illuminant having the temperature, T, between 2000°K and 4000°K:

$$\Delta\lambda = (7.23 \times 10^4/T) - 25.386 \text{ m}\mu.$$

A. C. Hardy[2] has suggested the use of a transparent plate ruled along the wave-lengths of the selected ordinates for 2848°K when placed over a spectrophotometric curve drawn on some standard size graph paper. Such a plate, displaced toward longer wave-lengths by the amount given by the above formula, will serve for the selection of the ordinates for any temperature, T, between 2000°K and 4000°K. The resulting wave-lengths will have an average error of less than 0.5 mμ, and the largest error, occurring at the shortest wave-length, will not be greater than 3.0 mμ. Errors exceeding 1 mμ occur only for the first one and the last two ordinates, and only within a few hundred degrees of the limits of the temperature range. The effects of such errors are quite negligible for the types of spectrophotometric curves commonly encountered. The selected ordinates for the I.C.I. $\bar{x}$ and $\bar{z}$ functions for general colorimetric computations do not conform with sufficient accuracy to any law of the above form to justify the labor of evaluation of the corresponding constants.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] *Handbook of Colorimetry* (Technology Press, Mass. Inst. Technology, Cambridge, Mass., 1936).
[2] A. C. Hardy, "A New Recording Spectrophotometer," J. Opt. Soc. Am. **25**, 311 (1935).

17. Photometry of Colored Light Sources. W. E. Forsythe, B. T. Barnes, and Ann L. Shrider, *Lamp Development Laboratory, General Electric Co., Nela Park, Cleveland, O.* (20 minutes.)

Six different kinds of lamps giving highly colored light—400-watt high intensity mercury arc, 10,000 lumen sodium lamp, 3200 lumen neon lamp and three fluorescent lamps, a pink, a green, and a blue lamp—were selected and a number of measurements made on their light output by twelve experienced observers at the laboratories at Nela Park. The characteristics of the observers' eyes were determined by having each measure the relative transmission of the Ives'[1] yellow and blue solutions which gave the so-called Y/B ratio for the different observers. First, comparison measurements were made of the luminous output of three 400-watt high intensity mercury lamps using the Lummer-Brodhun contrast photometer with colored screens to overcome the color difference and with two field sizes, that is, the regular 8–10° and the 2° field. The difference obtained varied with the observer and with the screen used, but the average results gave about a 4 percent increase for the small field. Next, the light output of a number of high intensity mercury lamps, 10,000 lumen sodium lamps and 1200 lumen green fluorescent lamps, was measured with the direct comparison photometer using a 2° field and a screen to equalize the color difference and with the Ives-Brady[2] flicker photometer. In order to obtain higher intensities with the fluorescent lamp, four lamps were mounted side-by-side and used as a source. The values obtained with the two photometers checked very well, considering the small number of observers and the range of eye sensitivity found.

Finally, the horizontal candlepower of the six types of lamps giving colored light was measured with the flicker photometer in terms of a tungsten lamp standard obtained from the National Bureau of Standards. In order to obtain sufficient intensity for this measurement, two of the neon lamps, four of the green fluorescent lamps and eight each of the other fluorescent lamps were measured together. The spectral intensity of each of these lamps was measured and the candlepower calculated from the spectral intensity by using the standard I.E.S. luminosity factor and good checks obtained, even with these few observers.

[1] Trans. I. E. S. **10**, 203 (1915).
[2] Phys. Rev. **4**, 222 (1914).

18. On the Magnitude of the Error Resulting from Fluorescence in Spectrophotometric Measurements. Kasson S. Gibson and Harry J. Keegan, *National Bureau of Standards.* (15 minutes.)

In spectrophotometers in which the sample is directly irradiated and the reflected energy then spectrally dispersed and measured, the error caused by fluorescence of the sample is small and probably negligible. However, this may not be the case in those spectrophotometers in which the energy is dispersed before any of it is permitted to fall upon the sample. In this latter type of instrument any fluorescent energy from the sample[1] reaches the detector undispersed and may produce a large error in the reflection (or transmission) curve.

In connection with the colorimetric specification of a certain phenolformaldehyde resin, the authors had occasion recently to measure the apparent reflectance of the resin relative to MgO. The color of the sample is a weak red, similar to Munsell R 5/4. The true colorimetric values are somewhat uncertain because of non-uniformity but the values of x and y for I.C.I. illuminant C approximate 0.410 and 0.313, respectively. However, the curve obtained on the G.E. recording spectrophotometer (an instrument of the second type, above) gave values of x and y with I.C.I. illuminant C approximating 0.385 and 0.346, respectively (corresponding to a yellow or brown sample instead of red). These erroneous values were caused by the fact that the curve was much too high in the yellow-green. This in turn

was traced to the fact that the sample was excited to a strong reddish fluorescence by the incident yellow-green energy, as may readily be demonstrated by irradiating it with the 546 mμ line from a mercury arc and viewing with a hand spectroscope. However, the effect may easily be overlooked because the sample fluoresces but weakly when irradiated with the 365 mμ line of the mercury arc.

The sample was also measured on two visual spectrophotometers of the first type above, but the results are rendered somewhat uncertain by fading of the sample and the insensibility of the eye in the end regions of the visible spectrum.

A remedy for these various errors and uncertainties would apparently be found if a photoelectric instrument could be designed such that the sample could be placed between two spectrometers, the first spectrometer selecting the wave-length band and preventing undue heating of the sample, the second spectrometer dispersing both the stray energy and the fluorescent energy.

[1] A. C. Hardy, *Handbook of Colorimetry* (1936); p. 3, footnote 5.

PROGRAM

For Sessions of The American Physical Society

Friday Morning at 9:30 o'clock

Room 401

Joint Session of The American Physical Society and The Optical Society of America

SYMPOSIUM

ON

THE OPTICAL PROPERTIES OF METALS

Invited Papers

1. **Some Simple Concepts in the Quantum Theory of Metals.** L. A. DuBridge, *University of Rochester.*
2. **The Experimental Determination of Optical Constants of Metals—Methods and Results.** J. B. Nathanson, *Carnegie Institute of Technology.*
3. **Derivation of Properties of Electrons in Metals from Optical Constants.** H. A. Bethe, *Cornell University.*

Friday Afternoon at 2:00 o'clock

Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 6–7)

1. A Scale for Predicting Nuclear Transformations. Vladimir Karapetoff, *Cornell University.*—Let atoms of an element X, of atomic weight A and atomic number Z, be bombarded by particles (or radiation) P of atomic weight a and atomic number u. Let the final product be an element Y and let the ejected particle (or radiation) be Q, of atomic weight b and atomic number v. Then

$$X_Z^A + P_u^a \rightarrow Y_{Z+u-v}^{A+a-b} + Q_v^b.$$

The sum of the weights on both sides of the equation is $A+a$, and the sum of unit electric charges is $Z+u$. A table of isotopes is constructed.[1] Let the bombarding particles be

He_2^2	H_1^1	γ_0^0
He_2^3	$H_1^2(D)$	n_0^1
He_2^4	H_1^3	n_0^2

These nine names are written on a piece of a thin celluloid scale in the positions indicated above, at the same distances as the elements in the table of isotopes, with a sharp point below each name on the scale. By placing a desired bombarding particle on the scale over any desired isotope in the table, the resulting products and the ejected particles may be read off directly.

[1] See, for example, Rasetti, *Elements of Nuclear Physics*, p. 154.

2. Maximum Energy of Ions from the Cyclotron. M. E. Rose, *Cornell University.*—The magnetic fields giving the greatest ion energy from the cyclotron are those which effect some compromise between the conflicting requirements of focusing and resonance.[1] The principal conditions for the magnetic field are (a) focusing force everywhere positive and (b) phase changes $\leqslant \pi$. It is also advantageous to make the field too large for exact resonance near the

center of the cyclotron and too small farther out; then the phase changes will partially cancel. Three types of magnetic fields have been investigated: (1) homogeneous field (phase change $\leqslant \pi/2$), (2) radially decreasing field with linear gradient and (3) the field which gives a constant total (electric+magnetic) focusing force. The energy in all cases is proportional to $(V_0AZ)^{\frac{1}{2}}$ where V_0 is the accelerating voltage, Z the atomic number and A the atomic weight of the ion. For protons and 50 kv dee voltage the maximum energies for the three fields are 11, 14, and 15 Mev, respectively. These energies may be obtained with intensities of about one-quarter the intensities obtained at low energy. However, very accurate shimming will be necessary to produce the required magnetic fields.

[1] H. A. Bethe and M. E. Rose, Phys. Rev. **52**, 1254 (1937); M. E. Rose, Phys. Rev. to appear shortly.

3. Possible Deviations from the Evaporation Model of Nuclear Reactions. H. A. BETHE, *Cornell University.*—If a nuclear particle of energy E comparable with the nuclear interaction energy V (or smaller) strikes a nucleus, it will lose practically all its energy in the "surface layer" of the nucleus. This process will cause an intense "local heating" of the part of the nucleus struck. The "heat" will then gradually spread over the whole nucleus. Since the local temperatures reached are very high it seems possible that a particle evaporates from the heated spot before the whole nucleus has come to thermal equilibrium. The probability of this occurrence depends on the heat conductivity k of the nucleus and is about $p=(a^2\omega/2\pi k)\times(2E/\Lambda)^{4/3}$ where a is the distance of neighbors, ω the natural frequency of vibration, and Λ the dissociation energy of the nucleus. For a solid body model, $k=\frac{1}{3}lu$ where $u\approx a/\omega$ is the "velocity of sound" and l the mean free path of elastic waves. l will certainly be small; assuming $l=a$ and $E=\Lambda$, we get $p\approx 1$. Thus many of the particles produced in reactions with heavy nuclei may have energies considerably higher than those calculated from the assumption of uniform nuclear temperature, although much lower than the energy of the incident particle. These "too fast" particles will be emitted preferably in the backward direction.

4. The Nuclear Isomers of In^{116}. ALLAN C. G. MITCHELL AND L. M. LANGER, *New York University.*—The isomeric periods of In^{116} (13 seconds and 54 minutes), produced by the capture of slow neutrons by In^{115}, have been studied with the purpose of determining the energy level scheme for In^{116}. The γ-ray of energy 1.4 Mev previously measured by the authors has been shown to have a period of 54 minutes. No γ-ray of 13-second period could be found. The percentage transmission by boron of resonance neutrons which effect the two periods has been measured and found to be the same within the experimental error, for both periods. The value obtained for the percentage transmission of 0.0252 g/cm^2 B (uncorrected for obliquity) is 73.5±3.0. The branching ratio $(R(13\text{ sec.}))/(R(54\text{ min.}))$ has been shown to be independent of the method of excitation and has the value 1.12±0.06. From the known beta-ray end points and the energy of the gamma-ray an energy level diagram has been drawn up which accounts for all the experimental facts. The two excited levels of In^{116} from which disintegration takes place are separated by 0.3 Mev, the level corresponding to the 13-second period lying higher. Gamma-ray transitions between these two levels can be forbidden by choosing quantum numbers which differ by 5 units.

5. A Method for Measuring the Nuclear Recoil in Beta-Ray Emission. J. HALPERN AND H. R. CRANE, *University of Michigan.*—The length of track produced in a cloud chamber by the recoil nucleus resulting from a beta-ray disintegration is too small to measure directly, even at the lowest pressure at which a cloud chamber can be operated. However, the recoil nucleus produces a number of ion pairs in the gas. For radio-chlorine, which has a 6 Mev upper limit, a maximum of about 15 ion pairs is expected, which is as many as the beta-ray produces in ½ cm path in air. The method of the present experiment is as follows. A gas containing radio-chlorine is placed in a cloud chamber. The clearing field is removed long enough before the expansion to allow the ions to spread out so that the resulting droplets can be seen individually. In many of the cases obtained, a small cluster of droplets appears at the beginning of the track. From the number of droplets an estimate is made of the kinetic energy of the recoil nucleus, and this is compared with that calculated from the observed energy of the beta-ray. Photographs will be shown of some of the tracks obtained.

6. Collimation of Slow Neutrons. J. G. HOFFMAN AND M. STANLEY LIVINGSTON, *Cornell University.*—A collimated beam of slow neutrons with an angular spread of 9 degrees is produced and analyzed with the aid of absorbers of B_4C and Cd, and detected in a BF_3 gas chamber actuating a linear amplifier and counter. The cylindrical collimators are made of concentric brass tubes between which B_4C is packed and around which Cd is fastened. The Cd (0.58 g/cm^2) absorbs 91.6 percent of slow neutrons detected in the BF_3 chamber; the B_4C (0.65 g B/cm^2) an additional 5.7 percent.[1] One collimator is fixed to the slow neutron source, the second collimator and detecting chamber are arranged to be swung about an axis midway between the two collimators. At zero angle a 260 mC Rn-Be source in the howitzer produces a beam of 285 counts/minute with a neutron background of 10 counts/minute. About ten times this intensity is obtained with the 1.2 Mev cyclotron as a neutron source. Variation of angles shows the collimation expected from the ratio of diameter to length of the collimator tubes. The instrument is being used to study the angular distribution of slow neutrons scattered from magnetized iron and other scatterers placed between the collimators.

[1] Hoffman and Livingston, Phys. Rev. **52**, 1228 (1937).

7. The Scattering of Fast Neutrons. R. F. BACHER AND D. C. SWANSON, *Cornell University.*—With a lithium target in the deuteron beam, the Cornell cyclotron has been used as a source of fast neutrons. It has been found that a large water shield placed close to the cyclotron forms quite a

good fast neutron screen. A pressure cloud chamber filled with either helium or hydrogen has been used to observe the recoils produced. Expansions behind the shield show only occasional tracks whereas in front of a hole through the shield large numbers of recoils are observed. Without any scatterer the recoils produced with the chamber in the "beam" show neutron energies up to 13 Mev. A scatterer of iron or lead of thickness, which on the basis of the known cross section was expected to scatter about one-quarter of the incident neutrons, was placed in the port, flush with the surface of the shield. Numerous tracks in the cloud chamber were now observed behind the shield and it was found that these led to neutron energies from 1 to 2 Mev. This indicates that the neutrons must lose a large amount of their energy in a single nuclear collision. This large energy loss, in turn, points to large interactions of the nuclear particles such as those which appear in the Bohr nuclear model.

8. Range and Specific Ionization of Alpha-Particles. M. G. HOLLOWAY AND M. STANLEY LIVINGSTON, *Cornell University.*—A shallow ionization chamber operating a linear pulse amplifier and counter is used for a study of the extreme end of the range of Po alpha-particles. The output pulses as measured by a variable thyratron bias are strictly proportional to the ionization in the chamber. Using 1 mm and 2 mm deep chambers the ionization near the end of the range is determined. For particles which stop in the chamber the ionization is directly proportional to the residual energy at the face. The difference in ionization in the two chambers gives directly the range-energy relation within the last mm. Ionization measurements in the 1 mm chamber were also taken throughout the last 2.8 cm of range, and the Bragg curve obtained. By combining these data a range-energy relation is computed, extending to within 0.005 cm of the end of the range, with an average error of less than 0.5 percent. The energy measurements are accurate to ±5 kilovolt (assuming the average energy loss per ion pair formed to remain constant), and the relative range measurements to ±0.004 cm. The mean range of Po alphas is found to be 3.802 ±0.010 cm.

9. Induced Radioactivity in Tellurium. GERALD F. TAPE AND J. M. CORK, *University of Michigan.*—In continuing the detailed study of induced radioactivity, tellurium has been bombarded in the cyclotron with (6 Mev) deuterons, with slow neutrons and with fast (Li) neutrons and observations made of the radioactive isotopes formed. In addition, the heavier element, iodine, and the lighter element, antimony, have been similarly treated. Chemical separation of the tellurium specimen after deuteron bombardment yields radioactive tellurium isotopes of half-lives: 66 min., 10 hr. and 8 days. The same bombarded specimen gives certain active iodine isotopes by proton capture. Bombardment by lithium neutrons yields activities in the tellurium whose half-lives are: 16 min., 10 hr. and 31 days. The antimony precipitate from the tellurium bombarded with deuterons gives the previously reported period of 60 days. Iodine bombarded with fast neutrons yields the well-known 26-min. period due to I^{128} and an activity of half-life 13 days undoubtedly attributable to I^{126}. Cloud chamber observations show that all of these radioactivity elements emit negative electrons. It is thus reasonable to associate the 8-day period with Te^{131} and the other three activities with Te^{127} and Te^{129}. There must be here, then, another example of isomeric isotopes. Gamma-rays are also observed as might be expected in this case. Since iodine has but a single stable isotope, it is evident that there are here two induced chain reactions. The active Te^{131} and Te^{129} emit electrons and become I^{131} and I^{129}. These in turn emit beta-particles and end as stable Xe^{131} and Xe^{129}.

10. Electron Pair Theory of Heavy Particle Interaction and the Rabi Effect. R. E. MARSHAK AND H. A. BETHE, *Cornell University.*—Rabi's atomic beam determination of the magnetic moment of the proton gave a value about 15 percent larger than Stern's, this discrepancy apparently lying outside the limits of experimental error. Young[1] suggested that an additional spin-spin interaction between proton and electron could account for the discrepancy. By coupling the heavy particles with the electron-positron field to get nuclear forces (Gamow-Teller[2] theory) one has at the same time the physical mechanism for the desired proton-electron interaction. The Hamiltonian (nonrelativistic approximation for heavy particles) was taken as

$$H=G\{C_1\Psi^*\Psi\psi^*\beta\psi+C_2\Psi^*\Psi\psi^*\psi+C_3\Psi^*+\Psi\psi^*\beta+\psi \\ +C_4\Psi^*+\Psi\psi^*+\psi\}$$

where Ψ is the quantized wave function of the heavy particle and ψ that of the electron. The diagonal element of this interaction with the electron eigenfunction in the hydrogen atom was calculated. The constants were deduced from the best values for heavy particle interaction, *viz.* ${}^3V_{NP}=75\ mc^2$, ${}^1V_{NP}=40\ mc^2$, range $=2.25\times10^{-13}$ cm. Assuming $C_3=C_4$, one finds $G=1.25\times10^{-6}\ (mc^2)(\hbar/mc)^3$ and $C_3=C_4=0.25$. With these values one obtains $V_{P_{\frac{1}{2}}}-=0.0052\ \text{cm}^{-1}$, which is 12 percent h.f.s. splitting. This is just what is required to explain Rabi's result although the exact quantitative agreement is of course accidental. The effect being of first order in G is not equivalent to the hyperfine structure caused by the magnetic moment of proton which is $\sim G^2$.

[1] L. A. Young, Phys. Rev. **52**, 138 (1937).
[2] G. Gamow and E. Teller, Phys. Rev. **51**, 289 (1937).

11. Factors Governing Yield from Ion Sources Using Focused Beams. LLOYD P. SMITH AND G. W. SCOTT, JR., *Cornell University.*—An analysis of ion sources in which ions are produced by a focused beam of electrons has been made. It is found that with usual electrode arrangements the effect of space charge on the number of electrons effective in producing ions together with the ionization cross section as a function of electron energy leads to a certain interelectrode potential at which the maximum ion yield is obtained. In particular, for the case of coaxial cylindrical electrodes, one of which is the cathode, the number of ions produced per unit volume per unit time varies approximately as $I_0^{1/2}V^{7/4}$ $(V<V_m)$ and as $I_0^{1/2}V^{-1/4}$ for $V>V_m$

where V is the potential difference between cathode and anode, I_0 the saturated cathode current per unit area, and V_m is the electron voltage for which the ionization cross section for the particular gas under consideration is a maximum.

12. A Linear Accelerator Using a Quarter Wave-Length Transmission Line. PAUL L. HARTMAN AND LLOYD P. SMITH, *Cornell University.*—A line or accelerator has been constructed with coaxial cylindrical electrodes mounted alternately on each side of a parallel transmission line so that the electrodes and line form a quarter wave-length resonant system. The part of the line carrying the electrodes is enclosed in an evacuated envelope made of glass tubing six inches in diameter. The radio-frequency voltage is applied to the transmission line near the short circuited end, thereby obtaining voltages across the electrodes considerably greater than that applied to the line. The radio-frequency (10 megacycles) voltage is generated by a three stage power oscillator. The present accelerator is designed to produce a beam of deuterons with an energy of about a half million electron volts. This type of accelerator has the advantage that the ion source and target are at ground potential and very accessible.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 6–7)

13. Stereoscopic Viewing and Measuring Instrument for Cloud Chamber Photographs. CREIGHTON JONES AND ARTHUR RUARK, *University of North Carolina.*—This instrument was conveniently built by using an old photostat machine as a basis. It makes possible four types of measurement: (1) full-size images of the chamber can be viewed stereoscopically; (2) track curvatures can be measured; (3) a translucent screen can be made to coincide with the real image of a track, so that angles between branches can be determined; (4) the direction of a track relative to axes fixed in the chamber can be measured directly on quarter-degree protractors. The important feature is the ease and speed with which measurements can be made. Slides will be shown.

14. Investigation of Hyperfine Structure of Spectral Lines from Atomic Beams. K. W. MEISSNER, *Frankfurt/Main. (Introduced by R. Ladenburg.)*—Atomic beams excited by electron impact and observed under 90° with respect to their motion give the sharpest spectral lines known, as they are nearly free from Doppler effect broadening. It is found that it is possible to get separation for lines which are only 2.5 thousands of an angstrom unit apart. In this way some "complete doublets" of different subordinate series were resolved for the first time and the splitting of their levels determined; furthermore new hyperfine structure patterns and isotopic shift of different elements were measured and the corresponding nuclear spins and moments calculated.

15. The Interval Rule in Hyperfine Structure. D. H. TOMBOULIAN AND R. F. BACHER, *Cornell University.*—Interferometric measurements have been carried out on λ7182 ($5s6p^3P_1 \rightarrow 5s6s^3S_1$) and λ7276 ($5s6p^3P_0 \rightarrow 5s6s^3S_1$) of In II to supplement the grating measurements of Paschen. Most of the states of In II have hyperfine structures which show deviations from interval rule arising either from perturbations of nearby states or from the electric quadrupole moment of the nucleus. The $5s6s^3S_1$ state is unusual in that there should be no quadrupole effect and the nearest neighboring states are about 3000 cm^{-1}. From λ7182, the $^3S_1$ separations are found to be 2.2088 cm^{-1} (11/2−9/2) and 1.8081 cm^{-1} (9/2−7/2). These give a ratio 1.2216 which agrees with the expected ratio 1.2222 from the interval rule, to 0.05 percent. From λ7276, the $^3S_1$ separations can be checked and are found to be 2.2081 and 1.8096 cm^{-1}. These measurements are essentially in agreement with the measurements above, the differences probably being due to the presence of the nearby helium line. From the observed separation one can conclude that the magnetic dipole interaction which gives rise to the interval rule is remarkably successful in accounting for the relative level spacing when there are no quadrupole effects and perturbation effects are negligible.

16. Spectra of Rare Earth Oxides. WILLIAM W. WATSON, *Yale University.*—Emission bands are reported for CeO and PrO. Vibrational quantum assignments have been made for four sparsely developed systems of CeO and one of PrO. Comparison of these is made with two known GdO systems (Piccardi) and one LuO system (Watson and Meggers). Nd has no evident oxide spectrum in the flame of the arc, and Meggers and Scribner report none for Yb. Many previously reported oxide spectra of rare earth elements are shown to be due to YO, LaO or to chlorides. Lower state vibrational frequencies range from 864 cm^{-1} for CeO to 842 cm^{-1} for LuO. The scarcity of bands, the general absence of long sequences, the usual singlet character and the frequently diffuse appearance of the bands for the oxides of the rare earths, all in marked contrast with the numerous systems of well-developed oxide bands for La which has the same outer electron configuration (ds^2), are attributed to the great prevalence of predissociation because of a high density of repulsion states. Where present these bands serve as easily identified spectral frequencies for chemical analysis.

17. The Optical Constants of Liquid Thallium. A. P. FRIESEN, *Bethel College, Newton, Kansas.*—Thallium was melted in a specially constructed furnace having glass observation windows free from strain. A steady flow of

hydrogen kept the metal surface optically clean. The source of light was a mercury arc. The optical system consisted of the usual train for the reflection method. Measurements were made for wave-lengths 5790A and 5461A. The values obtained for the indices of refraction were 1.304 and 1.153 respectively, while the extinction coefficients were 10.73 and 8.75, respectively. The reflecting powers were 76.35 percent and 75.78 percent, respectively.

18. The Relative Luminosity of the Yellow and Green Mercury Lines. W. E. FORSYTHE, B. T. BARNES AND ANN L. SHRIDER, *General Electric Co., Nela Park, Cleveland, Ohio.*—The relative luminous intensity of the yellow and the green mercury lines from an H-1 lamp was measured, with an Ives-Brady flicker photometer that has a 2° field using Corning glass filters to separate the lines, by sixteen selected observers. The Y/B[1] of the observers ranged from 0.667 to 1.113 with an average of about 0.99. The ratio for the two lines (yellow/green) found was 1.356. The ratio calculated from the spectral transmission of the screens, the average spectral intensity of three H-1 lamps and the standard I.C.I. luminosity factors was 1.332. This is not in agreement with results reported by Dresler;[2] however, he used a smaller field.

[1] Ives and Kingsbury, Trans. I. E. S. **10**, 103 (1915).
[2] Das Licht **7**, 81 (1937).

19. The Absorption Spectra of SrH and SrCl. KENNETH R. MORE* AND S. D. CORNELL, *Yale University.*—A high temperature vacuum furnace using a coil of molybdenum wire as a heating element was constructed for use in spectroscopic investigations. A temperature of about 1800°C has been attained with a power consumption of 2.5 kw. Strontium metal was placed in the core tube and the furnace filled with hydrogen to a pressure of about 60 cm of mercury. The band systems of SrH reported by Watson, Fredrickson and Hogan are observed in absorption. The analysis of the D system is extended by the use of known lower state combination differences. The appearance of lines of the C system arising from transitions to levels for which K' is greater than 18 shows the effect of pressure on the predissociation limit. The SrCl bands observed in emission by Parker are also observed and some of the sequences extended. The Boltzmann factor at the temperature used is such that appreciable fractions of the molecules in the ground electronic state exist in levels with values of v'' as high as 12. This makes it possible to observe in absorption sequences extending to members as high as (12, 12).

* Sterling Fellow.

20. Determination of Widths of Energy States: Argon K Absorption Limit. F. K. RICHTMYER AND L. G. PARRATT, *Cornell University.*—One must know the width of one x-ray energy state before one can construct from the observed widths of x-ray emission lines the complete diagram of widths of energy states (single ionization). Early investigations showed hope of obtaining directly this state width from the contour of an absorption limit. Recent work with solid absorbers indicates that profuse fine (sub-Krönig) structure completely obscures the width of the energy state in question. This is illustrated with the contour of the L_{III} limit for silver. Parenthetically, such fine structure is very promising as indicating possibilities in studies of energy zones of the solid state. With a gaseous absorber (argon, free from the solid state structure), several resonance absorption lines are found due to optical levels, superimposed on the K absorption limit. The width of each of these absorption lines, one of which is sharp and easily measured, gives directly the width of the K state of argon. The true K absorption discontinuity (complete ionization), an arctangent curve having this measured width, may be sketched in at the atom's periphery and three component resonant lines resolved.

21. Widths of Double-Ionization X-Ray Energy States. L. G. PARRATT, *Cornell University.*—Just as the energy level diagram is used to "explain" wave-lengths of x-ray lines, a diagram of *widths* of energy states (single-ionization) has been used to account for the *widths* of simple x-ray lines. An extension of this correlation to atomic states of double-ionization and the widths of the double-ionization (satellite) lines is attempted. Because of the uncertainties in the observed widths of most satellites, due to unresolvably overlapping adjacent components, one cannot ascertain from observed satellite widths the corresponding state widths. However, one may assume that the state of double-ionization has a width equal to the sum of the widths of each of the two single-ionization states involved. This says that the absence of the second electron does not influence the probability per unit time that either one of the vacancies will be filled. Then, knowing the single-ionization state widths, one may predict widths of satellite lines and use these widths as criteria (?) for sketching in under the observed complex contour *more* component lines than one finds direct experimental evidence for. Of 18 AgL series satellite lines measured, the width of one, $L\beta_2'$, 3.2 ev, is *less* than the width of the "parent" line, $L\beta_2$, 3.7 ev, which is tentatively ascribed to a decrease in the Auger width of N_V due to the $M_{IV,V}$ vacancy.

22. Absorption of Soft X-Rays in Beryllium, Carbon, Aluminum, Copper, Silver and Gold. C. L. ANDREWS, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—Absorption measurements for beryllium, carbon, aluminum, copper, silver and gold have been made for x-rays of wavelength 1.5A to 8.3A. Monochromatization was obtained with a modified Siegbahn-Thoraeus spectrometer, and the intensities measured with the aid of an ionization chamber. Most of the absorbing foils were made by evaporation of the metal onto a glass plate. A plot of $\log \mu A/\rho z$ against $\log z\lambda$ according to Jönson's rule for a universal absorption curve brings the data for all the elements except beryllium along a smooth curve. The curve for beryllium lies above the universal absorption curve. Since it is impossible to make sufficiently accurate chemical analysis for the impurity in the small amount of beryllium foil, no corrections for the impurities have been made. Plots of the absorption curve for beryllium in the neighborhood of the K discontinuity of iron show that much of the iron impurity is removed by fractional evaporation of the beryllium.

Friday Evening at 8:15 o'clock

American Museum of Natural History
Central Park West at 77th Street (77th Street Entrance)
Large Auditorium

Adolph Lomb Memorial Lecture

The Debt of the World to Optical Science

By

Dr. Harlow Shapley
Director of the Harvard College Observatory

Saturday Morning at 9:30 o'clock

Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 8–11)

23. The Mean Life of Rubidium 87. E. J. Konopinski* and H. A. Bethe, *Cornell University.*—Recent experiments[1] have shown that naturally radioactive rubidium is definitely Rb^{87}, having a mean life of 10^{11} years. The spin of Rb^{87} is known to be 3/2 while that of Sr^{87} has recently been determined by Kopfermann to be 9/2. Thus, for the first time, the spin change taking place during a "forbidden" β-decay process is known. With the experimental value of 250 kv for the maximum energy of the β-rays, the theoretical lifetime comes out to be $10^{10}/|M|^2$ years for the Fermi theory and about 1/10 as long with the Uhlenbeck-Konopinski modification or with the spin-dependent interaction of Gamow and Teller.[2] M is the nuclear matrix element and is expected to be less than unity so the agreement is satisfactory. The parities of the initial and final nuclei were assumed to be different so that the product of the nuclear wave functions contains spherical harmonics of order $L=3$ (and higher). Equal parities would make $L_{\min}=4$ in the F and KU theories and $L_{\min}=2$ in the GT theory, giving too long and too short a life, respectively.

* National Research Fellow.
[1] Mattauch, Hahn, *et al.*, Naturwiss. **25**, 189 (1937).
[2] Phys. Rev. **49**, 895 (1936).

24. Evidence Against the Existence of Heavy Beta-Particles. Arthur Ruark and Creighton C. Jones, *University of North Carolina.*—Jauncey suggested[1] that the slower beta-particles from a radioactive source may have rest masses greater than m_0, the electronic mass. On this basis $R\gamma=\gamma_m$; where Rm_0 is the mass, $\gamma=(1-\beta^2)^{-\frac{1}{2}}$, and βc is the velocity. γ_m is the value of γ for a beta-particle at the upper end of the velocity spectrum. For Ra E, $\gamma_m=3.44$. We have analyzed Champion's photographs[2] showing collisions of Ra E beta-particles with electrons. In 14 collisions of good quality, interpreted on the above basis, $R\gamma$ ranges from 1.65 to 2.74, most of the values being below 2. This is conclusive evidence against the hypothesis of heavy beta-particles; obviously it has no bearing on the possibility that the heavy cosmic-ray particles are electrons of exceptional rest mass.

[1] Phys. Rev. **53**, 106 (1938).
[2] Proc. Roy. Soc. **136**, 630 (1932).

25. On the Theory of the Neutral Particle. W. H. Furry, *Harvard University.*—In a recent paper[1] Majorana has shown that by the use of a special set of Dirac matrices the symmetry properties of the Dirac equations can be used to obtain a theory of the neutral particle in which neither negative energy states nor antiparticles ("holes") occur. If one introduces either a charge or a magnetic moment on the particle, it becomes necessary to admit the existence of antiparticles. The only other possibility of subjecting the particles to a force having a classical analogue is to use a "nonelectric force" as suggested some time ago by the writer.[2] The theory is here carried through without restriction on the form of the Dirac matrices, and for the case of a nonelectric force field. In spite of the fact that the theory does not admit the existence of antiparticles, pairs of particles can be produced by the field.

[1] Nuovo Cimento **14**, 171 (1937).
[2] Phys. Rev. **50**, 784 (1936).

26. Transmutation of Scandium by Th C′ Alpha-Particles. Ernest Pollard, *Yale University.*—The emission of protons from scandium under bombardment by Th C′ alpha-particles according to the reaction

$$Sc^{45}+He^4 \rightarrow Ti^{48}+H^1$$

has been observed. The energy distribution of the protons is complex, consisting of at least two groups with nuclear energy change $[Q]$ values -1.0 ± 0.4 Mev and -2.9 ± 0.4 Mev with some evidence of a more energetic group of $+1.0\pm0.5$ Mev energy change. Using this, together with Dempster's recent value for the mass of Ti^{48}, the value 44.9707 can be deduced for the mass of Sc^{45}.

27. Variations in the Relative Abundances of the Lead Isotopes. ALFRED O. NIER,* *Harvard University.*—A mass-spectrographic study of the isotopes of *common* lead shows that the relative abundances vary considerably in spite of a nearly constant atomic weight. The table below gives the results for several minerals. The numbers given are reproducible within at least one percent. A possible explanation for the variations is found if we consider the two oldest samples as primeval lead and the others as primeval lead contaminated by uranium and thorium lead. As the minerals listed are all essentially free from thorium and uranium, this may mean that the lead in them became contaminated before the mineral was formed. In view of these results the conclusions of Holmes[1] may have to be modified, inasmuch as he used the alleged constancy of common lead as an argument against the derivation of lead ores from acid or basic magmas. The samples were furnished and prepared by Professor G. P. Baxter.

MINERAL	GEOLOGICAL AGE IN M. Y.	204	206	207	208
Galena, Gr. Bear Lake	1300	1.00	15.9	15.3	35.3
Cerussite, N. S. W.	950	1.00	15.9	15.3	35.3
Galena, Germany	240	1.00	18.1	15.6	37.9
Galena, Joplin, Mo.	230	1.00	21.6	15.8	40.6
Cerussite, Wallace, Ida.	80	1.00	16.0	15.1	35.3
Wulfenite and Vanadinite, Arizona	25	1.00	18.4	15.5	38.2

* National Research Fellow.
[1] Holmes, Economic Geology **32**, 763 (1937).

28. The Scattering of Neutrons by Gases. H. CARROLL, P. N. POWERS, H. G. BEYER AND J. R. DUNNING, *Columbia University.*—It has been found possible to investigate the scattering of neutrons by gases through the use of a high pressure gas scattering cell. A collimated beam of neutrons about one meter long, from Rn − Be source to BF_3 pressure ion chamber, was utilized. Scattering measurements were made by interposing in the beam the high pressure scattering cell containing the gas to be investigated, and comparing the measurements with those having a calibrated "dummy" cell interposed. Approximately 300 K neutrons were utilized by making readings with and without Cd in the beam. Measurements have been made with a large number of gases. Preliminary results show that the proton (using H_2 in gas form) has a cross section of about 35×10^{-24} cm² compared with 45.0×10^{-24} cm² for the proton in CH_4.

29. The Scattering of Slow Positive Ions at Very Small Angles. A. G. EMSLIE, *Williams College.*—Scattering experiments with electrons and x-rays show that it is only in the angular region where diffraction or interference effects occur that the scattering is at all sensitive to the finer details of the fields of force involved. For positive ions, with their very short de Broglie wave-lengths, this important region is too small to be investigated by the usual electrical methods of recording, because of the relatively wide beams necessary to give measurable currents. A new method has been tried which avoids this difficulty and allows the critical angular region to be explored. The scattered ions are accelerated by a high voltage electrostatic lens and recorded on a photographic plate. The lens produces an angular magnification of the scattered pattern but does not distort it. The unlimited sensitivity of photographic recording permits a very fine beam to be used. Photographs of 150 to 300 volt lithium ions scattered by sodium vapor or by a polished nickel target show an unexpected uniform scattering up to angles of about half a degree. At greater angles the intensity falls off abruptly. With sodium vapor the plates also show a faint halo around the inner uniform disk.

30. On the Scattering of Neutrons by Paramagnetic Media. J. H. VAN VLECK, *Harvard University.*—Whitaker's experiments[1] have failed to reveal any excess of neutron scattering in paramagnetic materials over that calculated from the sum of the cross sections for purely nuclear scattering. Halpern and Johnson[2] showed that due to interaction between the neutron's magnetic moment and electron spin a large excess is to be expected if the wave-length λ of the neutron is large compared with the orbital radius r of the paramagnetic electrons. They note that negative experimental results are probably attributable to the form factor, i.e., nonfulfillment of the condition $\lambda/2\pi \gg r$. However, if the scattering is computed on the usual basis that the atoms can be treated as free independent units, the reduction due to the form factor disappears for forward scattering. The present paper shows that exchange coupling between the paramagnetic atoms makes them tend to scatter inelastically rather than elastically. The mean energy change is estimated to be roughly $k\cdot200°$ (140 cm^{-1}) for the materials used by Whitaker. In consequence the reduction due to the form factor is greater than for free atoms and persists even in the forward direction. The preponderantly inelastic character of the collisions thus makes it easier to understand the negative outcome of Whitaker's experiments.

[1] M. D. Whitaker, Phys. Rev. **52**, 384 (1937).
[2] O. Halpern and M. H. Johnson, Phys. Rev. **52**, 52 (1937).

31. Note on the Hartree Approximation Method for Calculating Nuclear Energies. V. F. WEISSKOPF, *University of Rochester.*—A method is given for estimating the order of magnitude of the successive approximations to the nuclear energy as given by the Hartree method. For nuclear potentials of the form Ae^{-r^2/a^2} the nth approximation, E_n, to the binding energy per particle is given by the expressions:

$$E_1 \cong c_1 A; \quad E_2 \cong c_2 A^2 M a^2/\hbar^2;$$
$$E_n \cong c_n A^n (Ma^2/\hbar^2)^{n-1} (r_0/(9\pi)^{1/3}a)^{n-1} \cdots (n \text{ odd});$$
$$E_n \cong c_n A^n (Ma^2/\hbar^2)^{n-1} (r_0/(9\pi)^{1/3}a)^{n-2} \cdots (n \text{ even}).$$

In these formulas $N^{1/3}r_0$ is the radius of a nucleus with N particles. The c_n are constants which vary as $n^{1/3}$. E_1 and E_2 have been calculated explicitly by Euler.[1] If $r_0/(9\pi)^{1/3}a$ can be considered as small, the first two approximations alone contribute essentially to the energy. It is possible by means of similar methods to compute the level density of the nucleus in the successive Hartree approximations, and to correct in this way the result of Bethe[2] for the free particle nuclear model. According to Bardeen[3] the first approximation leads to a decrease of the level density. The present calculations show that the second approximation

compensates this decrease completely and may even indicate a higher level density than that of Bethe's formula. As the above expressions show, the Hartree method converges only when $r_0/(9\pi)^{\frac{1}{3}}a$ is small and in this case the approximations beyond the second do not contribute appreciably to the level density.

[1] H. Euler, Zeits. f. Physik **105**, 553 (1937).
[2] H. Bethe, Phys. Rev. **50**, 332 (1936).
[3] A. Bardeen, Phys. Rev. **51**, 799 (1937).

32. Multipole Radiation Probabilities in Light Nuclei. M. PHILLIPS, *Connecticut College.*—According to the Hartree approximation the lowest group of levels in each of the nuclei Li^6, B^{10}, N^{14} contains both triplets and singlets described by the same space wave functions.[1] Between such states there should be magnetic dipole radiation corresponding to the proton and neutron magnetic moments. Application of the ordinary radiation formula yields the transition probability:

$$A=\frac{mc\epsilon^2}{3\hbar^2}\left(\frac{m}{M}\right)^2\epsilon^3\left|\sum_{p,n}(g_p\sigma_p+g_n\sigma_n)\right|^2,$$

where ϵ is the energy difference between singlet and triplet levels expressed in mc^2. Since $\epsilon\sim 6$ the consequent width of the singlet levels may be as large as a few tenths of a volt. The electric quadrupole radiation probabilities for transitions between levels having the same spin but different orbital angular momentum have also been estimated, and are somewhat smaller. The latter transitions would occur within the lowest group of states in all the nuclei considered in reference 1. The broadening in such deep lying metastable states may be surprising in view of level widths in the slow neutron range, and may again raise the question of the applicability of ordinary radiation formulae to nuclear processes.

[1] Feenberg and Wigner, Phys. Rev. **51**, 95 (1937); Feenberg and Phillips, Phys. Rev. **51**, 597 (1937).

33. Beta-Radiation from Activated Isotopes of Arsenic. B. R. CURTIS AND J. M. CORK, *University of Michigan.*—Although arsenic has but one stable isotope As^{75} there are at least three radioactive isotopes. These are as follows: (a) As^{76} from As^{75} by slow neutron capture (n, γ) or by deuteron bombardment (H^2, H) or from Br^{79} by fast neutrons (n, α); (b) As^{78} from Br^{81} by fast neutron bombardment (n, α), and (c) As^{74} produced by fast neutrons on As^{75} $(n, 2n)$. The half-lives of these activities are, respectively, 26 hr., 85 min. and 13.5 days. The first two emit negative electrons while the very long 13.5-day activity is radio-positive. The form of the beta-distribution for such a heavy long period positive emitter should be of particular interest. Measurements from the histograms indicate an upper limit of 0.65 Mev for the positron spectrum and about 2.3 Mev for the 26 hr. negative activity.

34. The Disintegration of Be by Alpha-Particles. H. L. SCHULTZ,* *Yale University.*—The excitation function for the emission of neutrons from Be under alpha-particle bombardment has been studied. Measurements of other observers have been extended by using the more energetic particles from Ra C′ and Th C′. Neutrons from a 4 mm air-equivalent Be layer were detected with the aid of a BF_3-filled ionization chamber surrounded by paraffin. The data obtained by this method give a pronounced resonance maximum in the yield curve at an alpha-particle range of 1.2 cm. The presence of a weaker resonance effect near the top of the barrier reported by Bernardini has not been confirmed. Above 4 cm range the yield is found to remain approximately constant until 7 cm range where it again appears to decrease. Interpretation of this behavior above the barrier height will be discussed.

* Sterling Fellow.

SATURDAY MORNING AT 9:30 O'CLOCK

Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 8–11)

35. The Apparent Discrepancy Among the Experimental Measurements of the Atomic Constants. RICHARD A. BETH, *Worcester Polytechnic Institute.*—The work of Birge and others[1] has emphasized that probably (on the basis of the statistical theory of errors) our present interpretation of experimental measurements of R_∞, e, e/m, and h/e is not consistent with our present views of the theoretical interrelations among these quantities. This situation is depicted by means of a new form of diagram, based on $R_\infty=2\pi^2me^4/ch^3=109737.42$ cm^{-1}, which treats all other atomic constants of the form $f=ke^\alpha h^\beta m^\gamma$ (in particular, e, m, h, e/m, h/e, h/mc, $he/4\pi mc$, $8\pi^2m/h^2$, and $hc/4\pi e^2$) in a mathematically similar way. This largely avoids a tendency to bias the question as to where the indicated difficulty may lie, in the form of its presentation. The diagram shows probable errors of measured quantities and permits a graphical estimate of probable errors of dependent quantities. It permits a simple graphical determination of any f from given values of any two others. Its relation to the Birge-Bond diagram[2] can be expressed in simple mathematical terms.

[1] R. T. Birge, Phys. Rev. **40**, 204 (1936), Nature **137**, 187 (1936) and Phys. Rev. **52**, 241 (1937). R. Ladenburg, Ann. d. Physik **28**, 458 (1937). J. DuMond and V. Bollman, Phys. Rev. **51**, 427–9 (1937). F. G. Dunnington, Phys. Rev. **52**, 501 (1937). J. DuMond, Phys. Rev. **52**, 1251 (1937).
[2] R. T. Birge, Science **79**, 438 (1934).

36. The Photon Emission of the Sun. ARTHUR E. HAAS, *University of Notre Dame.*—Quantum-theoretical computations lead to the result that the total number of photons emitted per sq. cm per sec. by a black-body in thermodynamical equilibrium is equal to $(4\pi\beta k^3T^3)/(h^3c^2)$, where k and h denote Boltzmann's and Planck's constants, re-

spectively, T the absolute temperature, c the velocity of light, and $\beta = 1/1^3 + 1/2^3 + \cdots = 1.20206$. This yields a value of $1.5 \times 10^{11} \times T^3$ photons per sq. cm per sec. The average energy of a photon in thermodynamical equilibrium is thus equal to $3kT \times \alpha/\beta$, where $\alpha = \pi^4/90 = 1.0823$. If we consider the sun as a black-body in thermodynamical equilibrium having a surface temperature of about 6000°K, we find the total emission to be about 2×10^{45} photons per sec. The sun would send about two photons per sec. through a sq. cm area at a distance of 10,000 light years (about 10^{22} cm). The total number of photons emitted by the sun in a period of about 20,000 years equals the total number of protons and neutrons contained in the sun. This fact seems to lead to some new aspects concerning the question of the photon production in the sun.

37. On the Theory of the Emissivity of Metals. EUGENE GUTH, *University of Notre Dame.* (*Introduced by George B. Collins.*)—(1) H. A. Lorentz derived for his free electron metal model the radiation law of Rayleigh-Jeans by computing explicitly the emissivity and the absorption of his metal model and then applying Kirchhoff's law. The derivation of Planck's law by considering an arbitrary body, e.g. any metal, can be obtained by a simple extension of Einstein's derivation of Planck's law. (2) The simplest radiation law based on correct approximations holds for the spectral emissivity of metals for long waves and at low temperatures, the dependence of the electric resistance of the metal on the frequency being neglected. Simple laws can also be derived by taking into account this dependence and neglecting the jumping of electrons in other energy bands which may eventually occur along with an excitation of the whole lattice. (3) More general laws can be obtained semi-empirically by using simple representations of the dependence of the optical constants of metals on the frequency. In the selection of these expressions, the results theoretically obtained for simplified models can be used.

38. Suggested Explanation of the Contradiction Between the Rayleigh-Jeans Formula and Experiment. PRESTON B. CARWILE, *Lehigh University.*—According to classical theory, degrees of freedom for radiant energy in a finite volume of free space may be thought of as modes of resonance for plane waves in the space. Resonance, however, depends on the existence of definite relationships at every instant of time, between incident and emergent waves at the boundary surface, as regards frequency, amplitude, phase, direction of propagation and state of polarization. It may be shown on classical grounds that these relationships do not exist at an interface between free space and a material substance. Therefore, modes of resonance in space have no meaning, and the Rayleigh-Jeans formula is not applicable to the partition of energy between space and a material body.

39. The Intensity of the Primary Cosmic Radiation and Its Energy Distribution. THOMAS H. JOHNSON, *Bartol Research Foundation, The Franklin Institute.*—The number of primary cosmic rays incident upon one horizontal square centimeter at the top of the atmosphere is computed by dividing the total energy spent in ionization in an infinitely deep column of air by the average energy of a single primary ray. The energy is found by integrating under the ionization-depth curves of Bowen, Millikan, Neher and Haynes[1] and the average energy per ray is computed from the minimum energy of the Lemaître and Vallarta theory, with a suitably chosen energy distribution function. Evidence for a low energy limit at about 4.0×10^9 volts is found. The number of primary cosmic rays increases from 0.03 per cm² per sec. at the equator to 0.36 per cm² per sec. at latitudes above 45°. The total cosmic-ray current to the earth, if all rays are positive, is 0.13 ampere or 8×10^{17} rays per sec. The distribution function for the number of rays can be represented by AV^{-n} where n is equal to or slightly less than 3, and V is the energy of a single ray.

[1] Bowen, Millikan and Neher, Phys. Rev. **52**, 80 (1937). Bowen, Millikan, Neher and Haynes, Phys. Rev. **50**, 992 (1936).

40. The Multiplicative Theory of Showers as Applied to Large Bursts of Cosmic-Ray Ionization. C. G. MONTGOMERY AND D. D. MONTGOMERY, *Bartol Research Foundation of The Franklin Institute.*—The energy spectrum of the electrons incident upon a small thickness of material is calculated, by means of the Bhabha-Heitler theory, from the observed frequency distribution of bursts of ionization produced by 100-ray showers, the effect of fluctuations being taken into account. The energy distribution obtained is of the form $1/E^{\alpha}$ where α is 2.5 for energies of the order of 10^9 volts and decreases slowly with increasing energy, in agreement with the energy distribution calculated by Heitler to explain the variation of cosmic-ray intensity with altitude. The number of electrons necessary to give the observed frequency of bursts is only about 1 percent of the total number of particles at sea level in the energy range 10^9 to 10^{10} volts. The incident energy spectrum found in this way is then used to calculate the number and frequency distribution of large bursts at large thicknesses of material. These calculated values differ considerably from the experimental ones. It may be concluded that, although the theory is satisfactory as a description of the building-up process of a large shower, some modification must be introduced to account for the penetration of showers through large thicknesses of matter.

41. On Sidereal Diurnal Variation in Cosmic-Ray Intensity. S. E. FORBUSH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.* (*Introduced by John H. Fleming.*)—Important implications concerning the origin of cosmic rays would follow were a sidereal diurnal variation in the observed cosmic-ray intensity definitely established. In addition to the possibility of emission or absorption in the Milky Way, there exists the apparent effect of galactic rotation investigated by A. H. Compton and I. A. Getting.[1] Modern statistical methods, developed by J. Bartel,[2] have been applied to data for 595 days from continuous records obtained from a Compton-Bennett precision recording cosmic-ray meter at Cheltenham, Maryland. The results indicate that if a 24-hour sidereal wave in cosmic-ray intensity actually exists, the data for 595 days at this station are statistically inadequate to establish the fact. This conclusion is substantiated by

analysis of data for 396 days from a similar instrument at Huancayo, Peru. Results for these two stations are compared with those which have been published for other stations.

[1] Phys. Rev. **47**, 817–821 (1935).
[2] Terr. Mag. **40**, 1–60 (1935).

42. Cesium Discharges Under Conditions of Nearly Complete Ionization.—FRED L. MOHLER, *National Bureau of Standards, Washington, D. C.*—The absolute intensity and intensity distribution of the continuous recombination spectrum have been used to measure the electron concentration and electron temperature in a high current discharge through a capillary 1 mm or more in diameter. In the pressure range 0.1 mm to 7 mm the intensity at high currents varies at the square of the pressure. At constant pressure the intensity rises to a flat maximum and then decreases with increasing current, the current density for the maximum ranging from 40 to 100 amperes per cm². The electron temperature is nearly independent of the pressure and increases nearly linearly with the current from 3100°K at 30 amperes per cm² to 7500°K at 200 amperes per cm². The intensity variation with pressure and current can be accounted for by Saha's equation with the assumption that the gas temperature is equal to the electron temperature. The maximum intensity is attained when about 0.9 of the gas is ionized and further increase in current lowers the ionization by pure temperature effect. Over a wide range of pressure and current nearly complete single ionization can be attained.

43. The Use of Isotopes in the Study of Ionization Processes of Polyatomic Molecules. J. M. DELFOSSE AND J. A. HIPPLE, JR., *Princeton University.*—In recent studies of hydrocarbons with the mass spectrometer, it has been shown that there are a great many different ions formed when the molecule is dissociated by electron impact. In many cases the appearance potential may be interpreted uniquely and the actual process may be determined. A greater insight into the processes occurring may be obtained from an additional study of the heavy hydrocarbons. An example of this is the study of the size of the peaks observed in *cis* and *trans* $C_2H_2D_2$. The ratio, (mass 15/mass 16) = 10, obtained with the mass spectrometer indicates that the most probable process is a splitting of the molecule into the two CHD radicals rather than CD_2 or CH_2. The ratio CHD^+/CD_2^+ is actually greater than the above figure since the impurities would tend to increase mass 16 more than mass 15. One of these impurities is perhaps asymmetric $C_2H_2D_2$. Other processes in this gas may be interpreted by the same method.

44. Ionization and Dissociation by Electron Impact in CCl_2F_2 and in CCl_4 Vapor. RICHARD F. BAKER AND JOHN T. TATE, *University of Minnesota.*—In the table is given the relative abundance of the ions formed in these gases at an electron energy of 75 ev. The appearance potentials are also given. The process $CCl_4 \rightarrow CCl_3^+ + Cl^-$ is a very probable one. An upper limit of 1.7 volts is fixed for the electron affinity of Cl_2. The heat of formation of CCl_2F_2 is calculated to be 4.7 ± 1 volts (108 ± 23 kcal).

Ion	Int.	A.P. (volts)	Ion	Int.	A.P. (volts)
CCl_4^+	0.02	11.0 ± 1.0	$CCl_2F_2^+$	0.3	11.7 ± 0.5
CCl_3^+	100.0	12.2 ± 0.2	CCl_2F^+	8.0	15.4 ± 0.2
CCl_2^+	23.5	16.0 ± 0.2	$CClF_2^+$	100.0	12.8 ± 0.2
CCl^+	27.8	17.1 ± 0.2	$CClF^+$	4.3	18.1 ± 0.2
		19.5 ± 0.2	CF_2^+	15.0	18.1 ± 0.2
Cl_2^+	0.35	16.4 ± 0.5	CCl^+	6.4	17.0 ± 0.5
		23.0 ± 1.0	CF^+	20.0	19.5 ± 0.5
Cl^+	27.6	19.1 ± 0.2	Cl_2^+	0.3	16.7 ± 1.0
C^+	14.4	23.5 ± 0.2	F_2^+	0.4	16.0 ± 1.0
CCl_3^{++}	1.6	31.8 ± 1.0	Cl^+	18.5	21.0 ± 0.2
CCl_2^{++}	0.8	34.0 ± 1.0	F^+	1.2	31.5 ± 0.5
Cl^-	99.5	1.3 ± 0.5	C^+	9.0	26.5 ± 1.0
		5.8 ± 0.5	CCl_2F^{++}	0.7	19.3 ± 1.0
		12.4 ± 0.2	$CClF_2^{++}$	0.9	35.5 ± 1.0
Cl_2^-	0.1	4.8 ± 1.0	F^-	7.0	1.4 ± 0.5
		17.0 ± 0.5			15.3 ± 0.5
C^-	0.01	—	Cl^-	16.0	2.9 ± 1.0
CCl^-	0.005	—			13.0 ± 0.5
			C^-	0.005	31.0 ± 1.0

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

45. The Energy Loss of Electrons in Lead. A. J. RUHLIG AND H. R. CRANE, *University of Michigan.*—Continuing previous work[1] on the absorption in carbon and lead of electrons having energies from 2 to 11 Mev, the losses in lead of electrons with energies both above and below this range have now been measured. For the low energy range electrons from radioactive P^{32} were sent through lead laminae of two thicknesses placed in the center of a cloud chamber. For the high energy group the electrons and positrons produced by the $Li + H^1$ gamma-radiation were used. The values found are again considerably greater than those predicted by theory, but are in good accord with the previous experimental values.

	Thickness of Pb	Average Incident Energy	Average Energy Loss
Electrons	0.038 mm	0.82 Mev	0.12 Mev
	0.066 mm	0.82 Mev	0.20 Mev
	0.38 mm	9.4 Mev	1.1 Mev
		12.7 Mev	2.3 Mev
Positrons	0.38 mm	5.8 Mev	1.1 Mev
		9.5 Mev	1.5 Mev
		12.3 Mev	2.3 Mev

[1] Turin and Crane, Phys. Rev. **52**, 63 (1937); **52**, 610 (1937).

46. Compressibility of the Alkali Metals. J. BARDEEN, *Harvard University.*—As a further test of the method of Wigner and Seitz[1] (for the calculation of the energies of the

monovalent metals), the pressure variation of the compressibilities of the alkali metals is determined and compared with recent experimental results of Bridgman[3] which extend to pressures of the order of 45,000 kg/cm². Improved calculation of the variation of the energies of Li and Na with volume yields the results given in the following table.

	Lattice Constant	Heat of Sublimation (kcal./mole)	Compressibility $\times 10^{12}$ (abs. c.g.s. units)	
			$v/v_0=1$	$v/v_0=0.808$
Li (exp.)	3.46A	46	7.4	4.2
Li (calc.)	3.49A	34	8.4	5.2
			$v/v_0=1$	$v/v_0=0.745$
Na (exp.)	4.25A	30	12.3	5.0
Na (calc.)	4.53A	23	12.0	4.6

Here v_0 is the volume at zero pressure and v is the actual volume; the smaller volumes in each case correspond to a pressure of about 40,000 kg/cm². The observed results are all extrapolated to $T=0°$K. The ion-core fields used by Wigner and Seitz were also used in the present calculation. A simplified method was used to determine the Fermi energy. Frohlich's[3] approximate analytic expression for the energies of the alkali metals suggests the following semi-empirical form:

$$W=a/v+b/v^{\frac{1}{3}}-c/v^{\frac{1}{2}}.$$

If the parameters are determined from (1) the lattice constant, (2) the energy, and (3) the compressibility (all taken at $p=0$) the expression gives values for the relative change of volume with pressure in close agreement with Bridgman's results. The constants so determined agree fairly well with Frohlich's theoretical values.

[1] Wigner and Seitz, Phys. Rev. **43**, 804 (1933); **46**, 509 (1934); Seitz, Phys. Rev. **47**, 400 (1935); Wigner, Phys. Rev. **46**, 1002 (1934).
[2] Proc. Am. Acad. (in press).
[3] Proc. Roy. Soc. **158A**, 97 (1937).

47. The Fine Structure of the Nuclear Ground Level of Li^7. G. Breit, *University of Wisconsin*, and J. R. Stehn, *Harvard University*.—To throw light on the form of the interaction energy between pairs of nuclear particles, the "approximately relativistic" equations[1] are applied to the fine structure of the ^2P ground level of the Li^7 nucleus. Since in this theory the requirements of relativistic covariance do not determine the spin-orbit interactions uniquely, there are adjustable parameters which are essentially coefficients of invariant additions to the Hamiltonian. These parameters are chosen to obtain agreement with the observed fine structure. Both the potential energies and the single-particle wave functions are assumed to have the customary Gaussian variation with space. The results are sensitive to the over-all wave function used and are thus of only qualitative significance. For the two p neutrons coupled into a ^1S state, the parameters can be ~ 1. But with the more likely symmetric-coordinate function of the three p particles (a linear combination of ^1S and ^1D for the neutrons), the parameters must be ~ 3. This does not correspond to the picture of one particle moving in a scalar field due to another; it requires instead an additional interaction having the transformation properties of an electromagnetic field.

[1] G. Breit. Phys. Rev. **51**, 248 (1936).

48. On the Saturation of Nuclear Forces. C. Critchfield and E. Teller, *George Washington University*.—Nuclear forces have saturation character as shown by the facts that both the total binding energies and the volumes of heavy nuclei are roughly proportional to the number of elementary particles (protons and neutrons) contained in the nucleus. The usual explanation is that the interaction between the heavy elementary particles is of the exchange type. An alternative explanation can be given with the help of the following assumptions: (1) a neutron or a proton can emit an electron-positron pair into one definite (or a few definite) quantum state of finite extension, L (this assumption violates relativity but secures convergence); (2) the average kinetic energy of the electron and positron in this state, E_{kin}, is small compared with the matrix element H' giving rise to pair emission. These assumptions lead to a potential which can not be written as a sum of interactions between pairs of heavy particles. If all particles are closer to each other than the extension, L, of the state into which the light particles may be emitted, the total potential is proportional to the number of particles. Setting $L\sim$electron radius this potential per particle is $\sim 137\ mc^2$ in rough agreement with experience.

49. On the Rotation of Atomic Nuclei. E. Teller, *George Washington University*, and J. A. Wheeler, *University of North Carolina*.—In Bohr's droplet model of the nucleus rotation of the nucleus as a whole should lead to levels lying only a few kilovolts above the fundamental state. Such levels would give rise to difficulties in the theory of the fine structure of radioactive decay and of metastable nuclear states. The Bohr model can be reconciled, however, with the absence of these low excitations since certain rotational states may be missing if some rotations amount merely to exchanges of nuclear constituents. Although this argument excludes a sufficient number of levels only for very symmetrical rigid geometrical configurations the rotational exchange becomes equally important for all other cases if the amplitudes of the zero-point vibrations of the constituents are comparable to their separations. Then, owing to the difficulty of identifying the path of a definite particle, the rotation of the droplet loses all similarity to rigid rotation unless the rotational quantum number, J, becomes higher than a certain J_{min} (for heavy nuclei $J_{\text{min}}\sim 8$). Under such circumstances the lowest excited state of the Bohr model will be inversely proportional to the mass of the nucleus, giving $\sim 10^5$ volts for the heaviest nuclei. Similar values are obtained from the independent particle picture.

50. The Rotational Transition in Solid Methane. John A. Wheeler and C. V. Cannon, *University of North Carolina*.—The face-centered crystal CH_4 shows a single transition at 20°K associated with an energy increase of 15.7 cal./mole. Clusius has recently found that CD_4 gives two transitions (21°K and 26°K; total energy increase of 78.5 cal./mole). We attribute the different *energy content* of light and heavy methane at low temperatures to the different zero point energy of their torsional vibrations, and

thus determine for the ordered state how fast the rotation potential

$$V(\theta_x, \theta_y, \theta_z) = \text{const.} + 2W(\theta_x^2 + \theta_y^2 + \theta_z^2)$$

increases for small rotational displacements θ_x, θ_y, θ_z from equilibrium. The simplest potential having the tetrahedral symmetry of the molecule and the symmetry demanded by the ordered state is

$$V(\theta, \varphi, \chi) = W\{[5\sin^4(\theta/2) - 6\sin^6(\theta/2)]\cos 2(\chi - \varphi) + [5\cos^4(\theta/2) - 6\cos^6(\theta/2)]\cos 2(\chi + \varphi)\},$$

where W has the same meaning as above. The rotational energy levels of the molecule are split in the proper way by this field to account for the entropy Rln16 observed for CH_4 at low temperatures. Calculation of the position of the altered energy levels and the mutual influence between molecules makes it possible to obtain a reasonable estimate of the heat content and degree of order at various temperatures and to check in order of magnitude the transition temperature calculated from the difference in zero point energies against the observed transition points.

51. The Potential Barrier in Ethylene Chloride. J. Y. Beach and K. J. Palmer, *Princeton University and California Institute of Technology.*—An electron diffraction investigation has been carried out on ethylene chloride to determine the extent of internal rotation around the carbon-carbon bond. Photographs taken at Princeton and at Pasadena both lead to the same result—that the potential barrier is 5 kcal. or greater. The procedure adopted was to calculate theoretical intensity curves assuming the potential function $A\sin\phi$. ϕ is the relative orientation of the two CH_2Cl groups. A is the height of the potential barrier and was varied from zero to infinity. Tetrahedral bond angles and covalent bond radii were assumed for the calculation. The *trans* model (A equal to infinity) is in good agreement with the photographs. The steric repulsion of the chlorine atoms was calculated by the method of Eyring and was found to give a potential barrier of 8.5 kcal. These values are compared with the value obtained by Altar from a Fourier analysis of the dipole moment data.

52. Nuclear Quadrupole and Magnetic Moments. Katharine Way, *University of North Carolina.*—Observations of nuclear electric quadrupole moments, q, reveal a lack of spherical symmetry in the distribution of positive charge, the more frequently found positive q indicating an elongated and the less common negative q a flattened shape. Nuclear models which have been proposed may be classified under (1) single particle model, (2) liquid drop model, and (3) central core plus single particle model. Rose and Bethe[1] have shown that model (1) will account for magnetic moments of light nuclei but to make predictions about q from this model seems difficult. Model (2) has been known to give magnetic moments, μ, of the correct order of magnitude. However, calculations will be presented showing that its q values are very much too small. Schmidt[2] points out that the interaction of an extra neutron or proton with an elongated core (variety of model (3)) accounts qualitatively for variation of μ with spin and for positive q's. Fano[3] suggests that the core has an α-particle structure which for maximum number of bonds will have an elongated more often than a flattened shape. It is concluded that model (3) seems the most promising.

[1] Phys. Rev. **51**, 205 (1937).
[2] Zeits. f. Physik **106**, 358 (1937).
[3] Naturwiss. **37**, 602 (1937).

53. Analysis of Hyperfine Structure of Mn I and an Indicated Value for the Nuclear Magnetic Moment. Russell A. Fisher and Edson R. Peck, *Northwestern University.*—New measurements of the hyperfine structure in visible lines of the Mn I spectrum provide a check upon disagreements reported by previous workers[1] as well as some new data. The observations are in general agreement with those of White and Ritchl and with their assigned value of $I = 2\frac{1}{2}$ for the Mn nucleus but yield some additional details of structure not previously reported. With the new data and graphical methods of analysis, we obtain values for the separation factors of 24 different hyperfine multiplets arising in configurations d^6s, d^5s^2, d^5sp, d^5ss and d^6p. Much of the analysis is supported by observations of the Bock-Goudsmit effect in Mn I lines.[2] Formulas expressing the observed splittings in terms of coupling coefficients of individual electrons are consistent with the data and provide experimental values for the electron coupling coefficients. All interactions are detectable but that of a $4s$ electron is most prominent, providing a coupling coefficient which depends somewhat upon the total configuration. If the ionization energy of the $4s$ electron in each configuration is taken as a measure of its coupling with the nucleus we obtain by Goudsmit's methods[3] values for the nuclear magnetic moment. Three computations based on independent data agree within ten percent upon a value of 1.1 nuclear magnetons.

[1] White and Ritchl, Phys. Rev. **35**, 1146 (1930). Mohammad and Sharma, Phil. Mag. **18**, 144 (1934).
[2] Fisher, Platt and Fry, unpublished data.
[3] Goudsmit, Phys. Rev. **43**, 636 (1933).

54. Hyperfine Structure of Boron, Yttrium, Rhodium and Palladium. D. T. Williams and L. P. Granath, *New York University.*—The spectra of boron, yttrium, rhodium and palladium have been investigated for hyperfine structure in the region 2400–4000 angstroms with a 20 cm quartz Lummer-Gehrcke plate. A Schuler tube with uncooled cathode was used as a source of radiation. The boron resonance doublet at λλ2497.73 and 2496.78 appeared too broad to reveal any asymmetry. Twenty-one lines in the yttrium first spark spectrum showed no significant h.f.s. Of seventy-one lines in the rhodium arc spectrum, only four, which end on the resonance level, appeared complex. The doublet structure observed seems to be due to absorption. A report by Sebaiya of recent date giving the same lines a genuine h.f.s. prompted the authors to obtain photographs using a tube with a water-cooled aluminum cathode as source. These photographs show no structure in the resonance lines. Twenty-six lines in the palladium arc spectrum revealed no significant hyperfine structure. It is estimated that any structure of magnitude greater than 0.05 cm^{-1} would be observable in the photographs of the three latter spectra, taken with the uncooled source. During the course of the research the iron spectrum was

found to be excited when the current through the source was about 1.5 amperes. The average half-breadth of two of the stronger unreversed lines, chosen at random, was 0.10 cm^{-1}.

55. Alkali Halide-Thallium Phosphors. FREDERICK SEITZ, *General Electric Co.*—An attempt is made to interpret the properties of alkali halide-thallium phosphors. The experimental basis of this interpretation is the work of Pohl and his numerous collaborators on these substances. It is concluded that the long wave-length absorption peaks of the phosphors which are not contained in the pure alkali halides are to be attributed to the excitation of the thallium ions. These are assumed to be distributed throughout the crystal, replacing alkali metal ions. The structure of the observed peaks is interpreted in terms of the details of the spectrum of Tl^+ and the probable effects of crystalline perturbations. The nature of the fluorescent and phosphorescent spectra is then correlated with the behavior of the normal and excited levels during the time after absorption and before optical radiation in which the crystal again comes to mechanical equilibrium. Distinction is drawn between two cases: That in which the excited Tl ion has no thallium ions among its twelve positive ion neighbors and that in which it has one. It is concluded tentatively that excitation to the lowest excited levels, associated with a triplet in the free ion, will give rise to fluorescence in either case, and that excitation to the higher, singlet level will lead to the alternative possibility of phosphorescence in the second case, but not in the first. The theoretical justification of these tentative conclusions involves assuming that the interactions corresponding to homopolar forces between the excited ion and its neighbors depress singlet excited levels more than triplet excited levels, and that singlets are depressed more when one of the neighbors of a Tl ion is another Tl ion than when none are.

56. Heavy Particle Interactions. D. R. INGLIS, *Princeton University.**—The simplest combinations of exchange operators in a symmetrical nuclear Hamiltonian give important results relating the stability of isobars. One may enquire what other combinations would be as satisfactory. From a simplified treatment of the instability of odd-odd nuclei, one has *two* approximate conditions on the coefficients, $g_s > g$ and $g_s > g + 2g_\sigma$ (remarks[1] to the contrary notwithstanding). The first arises from a singlet and the other from a triplet state of the unstable nucleus. These and a third condition, derived earlier for the proper stability of isobars, are all amply satisfied by a combination of operators giving as much binding as possible subject to the well-known conditions that there shall be no very heavy nuclei, whether "ferromagnetic" or not. (In this combination, the space-exchange term is not overwhelmingly predominant, the spin-exchange term being half as large.) This emphasizes the point that the remarkable success[1] of the simplest combination of operators does not conclusively favor it as a close approximation.

* On leave of absence from the University of Pittsburgh.
[1] E. Wigner, Phys. Rev. **51**, 947 (1937), especially footnote 10.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 329

57. Rate of Recrystallization in Polycrystalline Solids. L. A. YOUNG, *Carnegie Institute of Technology.*—A theory of rate curves for the transformation of a polycrystalline solid A into an allotropic modification B has been developed. For usual cases this will occur by nucleation and subsequent growth of these nuclei. We designate by $F_B(t)$ the fraction of A transformed to B at a time t after the transformation is initiated. Then $F_B(t) = n(t)\ g(t)$, where $n(t)$ represents the fraction of crystalline grains in which nucleation has occurred prior to t, and $g(t)$ the average fractional transformation of such grains at this time. Simple expressions for $n(t)$ and $g(t)$ have been derived. The first involves λ, the probability per unit time of nucleation occurring in a given grain; the second, a quantity T representing the average time necessary for complete transformation of a grain after nucleation. By proper choice of λ and T the function $F_B(t)$ can be made to fit experimental rate curves. Thus it is possible to determine separately the effect of impurities, change of temperature, etc., on the rate of nucleation and on the rate of growth of nuclei. This is of particular importance in gaining a better understanding of transformations in metals and alloys.

58. Relationship Between Internal Friction and Cold Work in Metals. CLARENCE ZENER, *College of the City of New York.*—A cold worked metal has residual internal stresses. When such a metal is vibrating, these internal stresses give rise to local heat currents, which in turn give rise to an increase in entropy. Hence these residual stresses are a source of internal friction. A quantitative theory of this internal friction is here given. Several experimental investigations have already shown that the internal friction of metals is increased by a large factor when cold worked. The theory here presented will enable one to interpret measurements of internal friction, made over a wide frequency range, in terms of the residual internal stresses. From such measurements it will be possible to calculate not only the energy associated with these stresses, but also the average dimensions of these stresses.

59. Some Unusual Demonstrations with Piezoelectric Resonators. K. S. VAN DYKE, *Wesleyan University.*—All of the following experiments, except 4, have been demonstrated at Scott Laboratory for a number of years but have not previously been shown outside. 1. *Spinning and trans-*

latory motions of a quartz sphere.[1] In a field produced by a 1000-volt generator tuned to certain of the sphere's natural modes of vibration, a 4 cm sphere resting on an eighth-inch hole in the bottom brass electrode orients itself so as to select a vertical axis about which it then spins at a rate of one to two revolutions per second. If the atmospheric pressure is reduced, the glow discharge patterns which appear on the surface of the spinning sphere are very striking. In another mounting the sphere progresses along a level track by sliding without rolling. 2. *The friction between a vibrating quartz surface and a stationary surface is almost zero.* 3. *A steel ball dropped onto a vibrating quartz crystal may rebound to a greater height than that from which it fell.* 4. *Spraying a liquid from a vibrating surface,* the vibrating crystal being the atomizer, and the burning of the fingers on touching a cold vibrating quartz resonator were first observed in 1924 with a low power generator. They are similar to some of the effects described later by Wood and Loomis[2] but produced by them on a much larger scale.

[1] Proc. I. R. E. **16**, 706 (1928).
[2] R. W. Wood and A. L. Loomis, Phil. Mag. **4**, 417 (1927).

60. The Velocity of Sound in Air. R. C. COLWELL, A. W. FRIEND AND D. A. MCGRAW, *West Virginia University.*—The velocity of sound in air has frequently been measured over long distances by means of explosives and chronometers. With modern electrical devices, the velocity may be found over short distances in a laboratory. An electron tube is connected in a circuit to produce 60 short pulses a second in a loud speaker. The sound pulses are received in a microphone and applied to the deflecting plates of a cathode ray oscillograph. A synchronous sweep is produced with a sixty cycle sine wave. When the microphone is moved approximately 5.75 meters, the pulse deflection moves along the sweep and returns to its original position on the screen. The time represented by this motion is one-sixtieth of a second. The average velocity for 100 measurements (ten readings at ten different temperatures) was found to be 331.54 meters/sec. at 0°C. By the use of the same sweep circuit in conjunction with a synchronous 3000-cycle timing wave, it is possible to measure the velocity of sound when the microphone is displaced a distance of 11–12 cm.

61. A New Electrostatic Method for the Determination of Young's Modulus. ROBERT B. JACOBS AND DENNISON BANCROFT, *Harvard University.*—A variable frequency precision oscillator is used to vibrate the sample through an electrostatic drive. The condition of resonance is ascertained by an electrostatic pickup feeding into the high impedance first stage of a 100-decibel amplifier. This method of drive and pickup has obvious advantages over either the piezoelectric or magnetic method, since each of the latter becomes ineffective at high temperatures. The present method has no such limitation and should be very valuable for the study of elastic properties of materials at very high temperatures. A further advantage, where metallic samples are concerned, is that they are used unloaded, thus obviating the usual load correction. The method is a rapid one, since the only adjustment necessary is a slight movement of the electrodes to compensate for the expansion or contraction of the sample at the different temperatures. Utilizing a steel cylinder ($\frac{1}{4}$" diam., 4" long) Young's modulus has been measured in the temperature range from 85°–373° absolute. The accuracy is of the order of one part in ten thousand.

62. Electric Impedance of *Nitella* During Excitation. KENNETH S. COLE AND HOWARD J. CURTIS, *College of Physicians and Surgeons, Columbia University.*—The membrane impedance characteristics of the long single cells of the fresh water plant *Nitella* are practically identical with those of single nerve fibers,[1] and their propagated waves of excitation are similar except for velocity. The changes in the alternating current impedance during this excitation wave in *Nitella* have been measured with the current flow normal to the cell axis and at 7 frequencies from 0.10 to 10 kilocycles per second. At each frequency the resting cell was balanced in a Wheatstone bridge with a cathode ray oscillograph, and the changes in the complex impedance during activity were determined from the bridge unbalance recorded by motion pictures of the oscillograph figure. An extension of the previous technique of interpretation of the transverse impedance shows that the dielectric impedance of the membrane which normally corresponds to a capacity of 0.9 cm^2 decreases about 15 percent without change of phase angle while the membrane resistance decreases from probably $2 \cdot 10^5$ ohm cm^2 to about 10^3 ohm cm^2 at the height of the excitation wave. The time relations of these changes and the accompanying action potential form a basis for the quantitative theory of nervous conduction.

[1] H. J. Curtis and K. S. Cole, Phys. Rev. **52**, 244 (1937). H. J. Curtis and K. S. Cole, in press.

63. A Stabilized a.c. Operated Ultramicrometer. DAVID L. ARENBERG AND PERCY M. ROOPE, *Clark University.*—An improved type of direct recording (Dowling) ultramicrometer was designed that reduced the difficulties found in the previous use of this instrument at high sensitivity. Two triode operated 6F6 vacuum tubes having a common power supply were placed as complex impedances in two arms of a Wheatstone bridge and operated as separate oscillators; the remaining arms were pure resistances. When the tubes were operated at such close frequencies that their heterodyne beat note disappeared, the balance was found to be extremely sensitive to frequency shifts in this locked region. Motion of condenser plates *vs.* galvanometer deflection gave sensitivities of 4×10^{-10} cm/mm and showed much higher sensitivity possible. To eliminate mechanical difficulties of producing small displacements only a portion of the total capacity was varied. Because of the symmetry of the circuits, both oscillators gave the same reaction to conditions of temperature, voltage, stray capacity, aging, etc., and eliminated these through their differential action. Tuned grid circuits of 3 megacycles were used and the set fed through a 110-volt a.c. voltage regulator.

64. A 600 kv a.c. Generator for the Production of Neutrons. T. R. FOLSOM, *Memorial Hospital, New York City.*—A novel method of cascading conventional x-ray transformers to produce potentials of 600 kvp is described.

Eight 75 kv, 40 ma transformers of the radiographic type are assembled in oil tanks made from ordinary earthenware jars and mounted in cascade on an insulated frame. The primaries of transformer units at different potential levels are energized and regulated by alternators driven through insulated shafts by synchronous motors. The voltage is applied to a two-stage, short-gap discharge tube with ion-source in the high voltage terminal and target at ground potential.

65. A Wide Range Ionization Current Meter. G. FAILLA, *Memorial Hospital, New York.*—The well-known (null) method of measuring very small unidirectional currents by varying the voltage across a condenser, has the drawback of requiring close and continuous manual operation during the compensation period, which in turn must be timed carefully. This practical difficulty may be overcome by using a potentiometer of uniform resistance and moving the slider at a constant speed by means of a synchronous motor and suitable speed reducer. The desired value of the compensating current is obtained simply by adjusting the voltage applied to the potentiometer. For some purposes it is desirable to be able to vary at will the speed of the slider from zero to a convenient upper limit. This may be done by a gear system like the automobile differential. Assuming that the drive shaft speed is constant, the speed of one driven shaft (carrying the potentiometer) may be varied from *zero* to any desired value by relatively small percentage changes in the speed of the other driven shaft—which may be brought about by simple means. Using an FP-54 detector a 10,000-fold current range may be obtained readily with a single condenser of fixed capacity.

66. A Vacuum Type High Speed Electrostatic Motor. C. S. SMITH, *University of Virginia.* (*Introduced by J. W. Beams.*)—A blade mounted on a tubular steel shaft was held between quadrant plates by a modified Holmes[1] magnetic suspension. The changes included passing the light beam under the control vane and elimination of all batteries. The blade was charged negatively and driven by alternating voltages on the quadrants generated in any one of three ways. Two of these involved automatic synchronization of the rotor, accomplished respectively by interruption of a beam of light and by an electrostatic pickup. The third consisted of synchronization with an independent oscillator. A rotor has been spun up to 3200 rev./sec, with approximately constant acceleration.

[1] F. T. Holmes, R. S. I. **8**, 444 (1937).

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

***67. An Alternative Description of the Compound Nucleus.** H. A. BETHE AND E. J. KONOPINSKI,[1] *Cornell University.*—The usual formulation of the theory of the compound nucleus meets with difficulties in joining the compound wave function at the surface to the wave function of the separated system. Consequently, (1) it is difficult to estimate the width of the compound levels, and (2) the method becomes unsatisfactory for very high energies when the widths are large and phase relations between incident and produced particle exist. These difficulties are avoided when the compound wave function is expanded as a sum of products of wave functions of residual nucleus and incident particle. The latter will obey a system of Schrödinger equations which are strongly coupled together, the strength of the coupling causing the "compound" character of the complete wave function. The coupling coefficients are certain integrals over the wave functions of the residual nucleus, and depend on the position of the incident particle in the nucleus. As an approximation, it is proposed to neglect this latter dependence. Then the coupled Schrödinger equations can be solved, the widths under various circumstances (high and low energy, with and without potential barrier, few and many possible states of the residual nucleus) can be estimated, and the transition to the Born approximation at high energies can be described.

* Paper No. 67 to be called for after paper No. 12.
[1] National Research Fellow.

***68. On the Diffraction of Electromagnetic Waves by Small Obstacles.** EUGENE GUTH, *University of Notre Dame. (Introduced by George B. Collins.)*—The special case, where the optical constants of a small obstacle differ but little from those of the surrounding medium, is treated by a method of successive approximations similar to Born's wave mechanical method. The new method is applicable to all forms of the obstacle as, for instance, for spheres, cylinders, ellipsoids. It is also applicable if the refractive index varies with the distance or with the direction. The results can also be obtained by replacing the wave equation for the Hertzian vector by an integral equation. This presentation reveals the relationship between the method of successive approximations and that of particular solutions, i.e., spherical harmonic developments, etc. Criteria for the applicability of the method are given. The method may be used for treating the transmission of light through turbid media containing small obstacles.

* Paper No. 68 to be called for after paper No. 44.

***69. The Lorenz-Lorentz Constant for Paraffin Oil Between 30 and 115 Degrees Centigrade.** A. P. FRIESEN, *Bethel College, Newton, Kansas.*—To measure the optical constants of certain liquid alloys underneath a protecting layer of paraffin oil it was necessary to measure the index of refraction of the oil at various temperatures. As a check the Lorenz-Lorentz constant was determined at each temperature. Only apparatus found in any sophomore physics laboratory was available. A telescope and a scale, illuminated by sodium light, were supported about two meters above a container in which a small mirror, silvered face up, formed a liquid wedge between mirror and the free surface of the oil. The distance between the mirror and the scale and readings of the reflected scale, with and without oil in the container, were the data needed for calculating indices of refraction. Densities were measured with a Mohr balance. Eight determinations between 30 and 115 degrees centigrade gave a value of 0.3211 ± 0.0005 for the Lorenz-Lorentz constant. This is in fair agreement with 0.3245 ± 0.0006, the value obtained by Poulter, Ritchey, and Benz[1] for constant temperature and pressures between 1 and 13,585 atmospheres.

* Paper No. 69 to be called for after paper No. 22.
[1] C. Poulter, Carter Ritchey and Carl A. Benz, Phys. Rev. **41**, 366 (1932).

***70. Optical Constants and Intermetallic Compounds.** A. P. FRIESEN, *Bethel College, Newton, Kansas.*—Determination of optical constants of liquid alloys seems to be a powerful method of detecting so-called intermetallic compounds. Large changes in the neighborhood of concentrations where compounds are known to exist were reported previously.[1] Work is in progress to determine these changes more in detail. The optical constants of twelve liquid thallium-bismuth alloys, between 0 and 30 atomic percent bismuth, have been determined. In this range the usual melting point curves indicate no compounds. If a compound exists, it must be highly dissociated. However, the optical constants decidedly change in the neighborhood of 25 atomic percent bismuth in a manner similar to the changes that occur for the sodium amalgams. Some evidence for the compound Tl_3Bi in e.m.f. data has been reported.[2] Work is begun in determining the changes of the optical constants of liquid thallium amalgams in the neighborhood of 33.3 atomic percent of thallium, where the highly dissociated compound Hg_2Tl is supposed to exist in the liquid state.

* Paper No. 70 to be called for after paper No. 69.
[1] Bull. Am. Phys. Soc. **10**, 13.
[2] R. Kremann and A. Lobinger, Zeits. f. Metallkunde **12**, 246 (1920).

71. Spectrographic Study of the Distribution of Mineral Elements in Sugar Cane. STANLEY S. BALLARD, *University of Hawaii.*—Samples of the ash of various portions of a single sugar cane stalk have been analyzed by the qualitative

spectrochemical methods developed in the spectroscopic laboratory of the Experiment Station of the Hawaiian Sugar Planters' Association.[1] The presence in sugar cane of eighteen metals and semi-metals has been established. Large differences were found between the numbers and amounts of elements occurring in the several parts of the plant tested (the leaves, the growing point region, and various sections of the stalk). The results for the common plant constituents phosphorus, potassium, calcium, magnesium, silicon and iron conformed to what the plant physiologist would expect, but data on the less common elements were more striking. More critical analyses of this type are now in progress. Their improvements over the preliminary analyses lie in better sampling, in more careful preparation of samples (including ashing at 300°C), in using weighed portions of ash that are computed in terms of equal dry weights of the original plant materials, and in the use of a more exhaustive spectrographic technic which should reveal the presence of very small traces of the minor elements. Samples were prepared with the aid of Arthur Ayres, Assistant Chemist, Experiment Station H.S.P.A.

[1] S. S. Ballard, Phys. Rev. **52**, 253A (1937).